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TUMOUR OF THE URINARY BLADDER AS AN OCCUPATIONAL DISEASE IN THE RUBBER INDUSTRY IN ENGLAND AND WALES

BY

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Introduction

During the investigations incidental to a large-scale survey of occupational tumours of the urinary bladder in males employed in a section of the British chemical industry (Case, Hosker, McDonald, and Pearson, 1954), it was found that men engaged in the manufacture of a certain rubber antioxidant of the primary aromatic amine class, which was used to a limited extent in the rubber industry, had suffered heavy casualties from bladder tumour. It therefore seemed desirable to see whether the risk of occupational tumour of the bladder extended into the rubber industry, and co-operation from this industry in the county borough studied was readily obtained. As soon as the trend of the investigation became apparent in 1949, the British manufacturers of the antioxidant voluntarily and promptly ceased to manufacture the product, and the British rubber industry ceased to use it and destroyed their existing stocks.

The antioxidant, which was a formaldehyde condensation product of alpha-naphthylamine and beta-naphthylamine, contained a small proportion (about 2·5 per cent.) of uncombined naphthylamines, and pilot experiments on a Banbury mixer showed that quantities of naphthylamines were vaporized during the processing of a rubber "mix" (Williams, 1949). In addition, the condensation process also led to the formation of 1:2:8:9-dibenzacridine (numbering according to the preferred system, Albert, 1951). This substance has been isolated from the antioxidant, and a highly purified synthetic speciment has been shown to be locally carcinogenic when injected subcutaneously into mice (Case, 1952).

Historical Survey

The concept of cancer (not specifically of the bladder) occurring as an occupational disease in the rubber industry is by no means new. This is illustrated by the following extract referring to the triennium 1929–31 (Registrar-General, 1938):

> Skilled Workers in Rubber (No. 207) returned a general mortality ratio of 110, with a probably significant excess for cancer (138). . . . The cancer excess of thirteen deaths was distributed over the buccal cavity and pharynx, 2; oesophagus and stomach, 5; skin, 2; and other sites, 4. A similar cancer excess was recorded in 1920–22. . . . There can be little doubt that the cancer excess has an occupational origin.
>
> The indices used are standardized mortality ratios (S.M.R.).

Bladder cancer as an industrial risk has also exercised the minds both of investigators and of the industry itself. Thus Hueper (1949) lists rubber occupations as being suspect on theoretical grounds, and both Schidrowitz (1944) and the Editor of the *India Rubber Journal* (1949) speculate about the possibility that phenyl-beta-naphthylamine in synthetic rubber and antioxidants made from alpha- and beta-naphthylamines in processed natural rubber might constitute a hazard.

It is also of interest to note that Dr. S. A. Henry, in a report to H.M. Senior Medical Inspector of Factories on a case of bladder tumour in the Chemical Industry, wrote as long ago as 1931:

> During my visit to the works I learned that naphthylamine is coming into considerable use in calico printing works and in rubber works, and this information may be helpful to us in our general investigation of the subject of occupational cancer of the bladder (Henry, 1931).

Falk, Steiner, Goldfein, Breslow, and Hykes (1951) and von Haam and Mallette (1952) isolated a series of carcinogenic aromatic hydrocarbons from processed rubber, and also from some carbon blacks used in rubber.

Technological History

Rubber technology is a vast and complicated subject, but fortunately only a few aspects of it now appear to be relevant to the present inquiry. Most of the rubber industry is concerned with the production of tyres. Barron (1947), to whose book the present authors are indebted for much of the technological history in this paper, states:

> . . . about 80 per cent. of all rubber is used in the motor industry, mainly for tyres . . . A large proportion

* Sometime Royal Cancer Hospital Research Scholar.

of the remainder goes into what are known as mechanical goods, which include such articles as belting, packings, moulded goods, hose and innumerable types of products.

Basically, the processing of the rubber for nearly all these products is similar.

The processing of the raw rubber includes mastication and the mixing in of chemical additives, followed by calendering. During these processes the mass is exposed to heat, and in many types of machinery any volatile matter can escape to the ambient atmosphere. The rubber "mix" is worked whilst hot to form the required product, usually by either extrusion or moulding, and the subsequent vulcanization is usually carried out in steam-heated autoclaves. Thus operatives working in the rubber mills, mixing department, calendering, moulding, extruding, curing, or vulcanizing processes will all be exposed to the chemicals added to the raw rubber.

If indeed the rubber industry offers a cancer hazard to workmen employed therein, and if the possibility that raw rubber itself is carcinogenic is rejected, then, in the present state of our knowledge of carcinogenic agents, the important additives which might be suspected of containing a carcinogenic factor or factors amongst them can be divided into three groups. Historically, the use of these three groups became widespread throughout the industry at different times:

(1) *Organic Accelerators.*—The discovery of the properties of accelerators was made *c.* 1906, though the use of organic accelerators only became "quite general and systematic" (Barron, 1947) after 1920.

(2) *Carbon Black Reinforcing Agents.*—The use of large quantities of gas-black as a reinforcing agent became general also about 1920.

(3) *Organic Antioxidants.*—These were introduced after 1925, becoming general towards the end of the decade 1920–29.

In addition to members of these groups, plasticizers, softeners, fillers other than carbon black, inorganic colouring materials, and organic dyestuffs may be added according to the nature of the final product. There seems at present no reason to suspect these compounds of being possessed of possible carcinogenic properties.

The organic accelerators cover a wide range of products, but may be broadly classified as consisting of aldehyde-amines, guanidines, carbon disulphide accelerators, and mixtures of members of these groups. The carbon blacks are obtained by a variety of processes, the essence of all of which is the incomplete combustion of some form of hydrocarbon. The antioxidants also cover a wide range of chemical products, which in some cases overlap the accelerator group and cannot all be clearly differentiated from it. They may be broadly classified as hydrocarbon waxes, phenols, primary aromatic amines, amino-phenols, phenolamine salts, aldehydeamines, secondary alkaryl-amines, substituted diphenylamines, secondary naphthyl-amines, acetoneaniline reaction products, and benzimid-azoles. Usually not more than one of these substances would be used in any one rubber "mix", many of them are in fact interchangeable, and the end results on the finished product might differ but slightly.

It is perhaps desirable at this stage to emphasize that there is no *a priori* reason to suspect all or many of the compounds listed above of being potentially carcinogenic. Two only, according to our present knowledge (*i.e.* in 1949), might be regarded as possibly able to give rise to a potential occupational bladder tumour hazard. One of these belongs to the aldehydeamine class and might contain or liberate free alpha-naphthylamine. The other, already mentioned in the introduction, is listed in the primary aromatic amine class (Barron, 1947), but could more properly be assigned to the aldehydeamine class, and might contain or liberate free alpha- and beta-naphthylamine, as well as containing 1:2:8:9-dibenza-cridine. Should benzidine, the antioxidant properties of which were discussed by Heywood (1943), come into wide-spread use, this also would constitute a potential hazard which would require consideration.

It is necessary to emphasize that, despite fairly intensive animal experiments (Hartwell, 1951), no evidence has been found to suggest that the substituted naphthyl-amines, such as the phenyl- or ethyl-naphthylamines, are in any way carcinogenic, and that so far clinical and statistical experience has not raised any suspicion of a hazard in the manufacture or use of these derivatives.

Scope of the Investigation

The particular antioxidant considered was introduced about 1927–28, but it is likely to have been the choice of only some firms. The hypothesis that this particular antioxidant introduces an occupational bladder tumour hazard requires the demonstration of an excessive number of bladder tumours in workmen engaged in rubber occupations, and this increase must persist or be enhanced in factories where the particular substance had been used. Furthermore, the excess should not be present in similar factories where the substance had not been used. These criteria, though necessary, are not both necessary and sufficient, since it would not be possible to reject absolutely the possibility that some other substance used was the causative agent.

The expected induction time of the tumours, if such do occur, may be expected to be of a similar character to that found in the chemical industry, that is about 18 years, with a standard deviation of 7 years, the distribution being normal and the parameters being unaffected by the intensity or duration of the exposure (Case and others, 1954). Very few tumours would be expected to have become manifest by 1935, after which date the rate of appearance would be expected to accelerate until about 1946, after which it should remain approximately constant unless the risk is abolished, when it should slowly subside after a further period of about 18 years.

If the hypothesis is true, it would be reasonable to expect that the excess cases would appear after 1935 and not be detectable before that time. This is not a necessary condition for the hypothesis, since it is theoretically possible that the antioxidant might have replaced another dangerous substance.

The relatively recent date of the expected occurrence of the occupational tumours would also mean that a high proportion of the cases developing will be still alive by 1951, the last year to be considered, since a fair proportion of the cases survive more than 5 years from the time of onset. This means that a study of the most accurate records available, namely death certificates, may not yet give conclusive evidence of the existence or, equally important, of the non-existence, of a risk.

These studies were directed therefore towards elucidating

(1) whether there is an increased risk of tumour of the bladder in workmen engaged in rubber occupations compared with the total male population of England and Wales;

(2) whether this risk persists in areas where the particular antioxidant under consideration is known to have been used;

(3) whether the risk, if it exists, shows a temporal change with 1935–36 as a pivotal point.

In view of the expectation of the survival time attenuating the value of death certificates as a criterion, morbidity figures have also been studied where possible.

Sources of Information and Methods Used

In the investigation of the occupational hazard in a section of the chemical industry (Case and others, 1954), no distinction was drawn between the condition sometimes described as "papilloma" of the bladder and carcinoma of the bladder, the two manifestations being considered as a disease entity, tumour of the bladder. This convention is adhered to in the present studies.

In this previous investigation the reality of the hazard was demonstrated by the use of a form of analysis that may conveniently be designated "comparative composite cohort analysis". This is a technique whereby the actual occurrence of an event in a population defined by individual name and working environment, with the age and date of entry into the environment, is observed, and the result compared with what would be expected from a "general population" or population not exposed to a specific risk of the event, observed for the same length of time. Thus the unit of the analysis is the cohort, which is defined by two or more characteristics, each defining a sub-cohort, *e.g.*, age, environment, and date of entry into environment. These sub-cohorts are later combined by summation of the expected frequency of the event, introducing the composite element.

The particular advantage of this type of analysis when applied to environmental problems is that much more data can be used than in the alternative techniques, since withdrawal from the environment does not affect the method of estimation. The method is an elaboration of the cohort principle discussed by Kermack, McKendrick, and McKinlay (1934) and Barclay and Kermack (1937), and subsequently developed further by Whelpton (1952) and Taylor (1952) for problems of fertility analysis.

The specific application of comparative composite cohort analysis to occupational tumours of the bladder for males in England and Wales, with Tables to facilitate the easy application of the method, has been discussed at length by Case (1953a, b). When applied to industrial hazards, however, this method presupposes the full and detailed co-operation of the industry concerned. In the previous investigation (Case and others, 1954) a prior appreciation of risk had secured this co-operation. In the present investigation there has been no prior appreciation of risk, and therefore this method of analysis was not feasible.

In the absence of the detailed information that would be required for the foregoing type of analysis, another less precise method is resorted to. This is the standard method used by the Registrar-General in the "Decennial Supplements, Occupational Mortality Tables", where a yearly estimate of the employed population in the relevant occupations is broken down into age groups, and from this an estimate of the expected frequency of the event under consideration is made by the application of the age-specific rates for that event determined for the general population. The determination of the observed number of events requires that the subject shall be in the specified environment at the time that the event takes place. Thus all the information that can be utilized is that relating to workers who, once having entered the specified occupation, remain in that occupation until the event being studied overtakes them. The increase of precision of the former method of analysis described above over this latter form will depend upon the labour stability of the industry concerned, but may easily be of the order of five-fold or more.

In the present studies the environment considered is defined by the list of rubber occupations in the Census, Occupation Tables (General Register Office,

1924, 1934), qualified further by the requirement that the occupation must have been an insurable occupation under the pre-1948 regulations (*i.e.* Unemployment Insurance Act) unless age was the sole condition not fulfilled. Assistance in allocating men to these occupations was obtained by the use of the "Classification of Occupations, 1950" (General Register Office, 1951). The event, in the mortality studies, is a death certificate mentioning tumour of the urinary bladder (*cf.* Case, 1953a), and in the incidence studies for the region specified, a hospital record of having suffered from tumour of the urinary bladder.

The sources of information available to us were:

(1) All death certificates mentioning tumour of the urinary bladder in males for England and Wales for the years 1921–51 inclusive.

(2) All cases of bladder tumour notified to us by, or found by us in the records of, all the hospitals in a large county borough for the years 1936–50 inclusive. The county borough was also one of the important centres of the rubber industry, and it was known that the particular antioxidant under consideration had been used there from 1928 to 1949.

Since it is uncommon for a case of tumour of the bladder not to be treated or investigated in a hospital at some time during the course of the disease, and since the standard of record keeping of the hospitals in this particular area since 1936 has been of above average efficiency, it is believed that an almost complete coverage of the area has been achieved. As some sort of a check on this belief, the data relating to persons normally resident within the county borough were abstracted, and the annual age-specific "report"* rates for the county borough calculated.

Similarly death certificates for persons normally resident within the county borough were abstracted from the national data, and the mean annual death certification rate (*cf.* Case, 1953a) was calculated for the same age groups for the same years. These figures are shown in Table I. In all age groups except the ultimate one, the "report" figures exceeded the certification figures (ignoring the age group under 25, where the rates are equal but the number of events very small, being only three in each case). This suggests that no serious deficit in reporting has occurred in any age group. The greater certification rate in the ultimate group is of course to be expected, since many of the cases will have been included in the "report" figures in earlier age groups.

A further check on the adequacy of the "report" figures can be obtained by using the completeness of death certification figures quoted by Case and others (1954) for co-operating hospitals throughout the country.

* "Report" in these studies is defined as those cases appearing in the hospital data, whether alive or dead, and whether actually reported by the hospital or found in the hospital records by us.

TABLE I

AGE-SPECIFIC CERTIFICATION RATES AND "REPORT" RATES FOR TUMOUR OF THE BLADDER (PER MILLION LIVING PER YEAR) CALCULATED FROM FIGURES FOR THE 15-YEAR PERIOD 1936–50

County Borough

Age	Death Certification Rate	Hospital "Report" Rate
Under 25	2·55	2·55
25–	2·55	13·91
35–	11·10	42·61
45–	78·88	160·46
55–	204·34	313·27
65 and Over ..	755·45	577·78
No. of Cases ..	602	809

Here it was shown that out of 819 patients "reported" who had since died, 81·3 per cent. had bladder tumour mentioned on the death certificate. If we apply this rate to the county borough in question, it is possible to calculate that since 602 death certificates were found for the 15-year period, 740 "reports" would have been necessary to obtain this number. If the survival time is assumed to have remained constant for the whole period of collecting all the cases, and if the increase of incidence discussed by Case (1953a) is ignored, then 740 "reports" should be expected in the 15-year period under discussion. In fact 809 reports were found, 109 per cent. of the expected number. This reasonably good agreement lends further support to the belief that the "report" rates are not seriously underestimated.

(3) Estimates of the male civil population by age groups for England and Wales for each year from 1921 to 1951 inclusive.

These were obtained from the appropriate copies of the "Statistical Review of England and Wales" (Registrar-General).

(4) An estimate of the mean annual male population by age groups for the county borough for the years 1936 to 1950.

These figures are based on the "1931 Census", the "1951 Census 1 per cent. samples" (General Register Office, 1934, 1952), the "1939 National Register" (National Register, 1944), and the "1947 Estimates of Sex and Age Distribution of the Civilian Population" (General Register Office, 1949). These figures were used in computing the age specific rates for the county borough discussed above.

(5) Estimates of the insured population employed in the rubber industry for each year from 1923 to 1951 for England and Wales, and for 1936 to 1950 for the county borough.

Some of these figures are published in various official sources, such as the different volumes of the "Abstracts of Statistics for the United Kingdom" (Central Statistical Office) and the remainder were provided by courtesy of the Ministry of Labour and National Service.

(6) The numbers engaged in the rubber occupations (as opposed to the rubber industry) for England and Wales, and also for the county borough, for 1921, 1931, and 1951.

"Census Reports", General Register Office (1924, 1934, 1952).

(7) The age composition of the population engaged in the rubber occupations for England and Wales for 1921, 1931, and 1951, and for the county borough for 1921.

"Census Reports", General Register Office (1924, 1934, 1952).

(8) Replies received to a questionary relating to occupational history sent to the hospital patients, or to a near relative, for the county borough.

Explicit written permission from the competent hospital authorities was obtained before this was done. The reply rate was about 30 per cent.

(9) Occupational histories as and when stated on the hospital records of the cases reported.

Not more than 20 per cent. of histories gave any occupation, and in very few cases was the information sufficiently explicit to be of any value.

(10) Replies received from the medical officer of one rubber factory in the county borough relating to specific queries about patients' occupational histories.

From these data it was possible to compute or extract the following information:

(*i*) All cases of bladder tumour, alive or dead, who may be assumed, from what is known of their occupational history from any source, to have come into contact with hot rubber during its processing, or to have worked on machines contaminated with the chemical additives. Only 52 of these 85 cases can be used statistically, but they are all set out *in extenso* in Table II (overleaf) as a record which may be of interest at some subsequent date. The cases in Table II may be subdivided into the following categories:

(*a*) The actual number of cases where the death certificate mentions tumour of the bladder where the deceased was employed in an insurable job (Unemployment Insurance Act Regulations) which is classified as a rubber occupation. These figures have been found for both England and Wales for the years 1921 to 1951 inclusive (35), for the same area for 1921 to 1935 inclusive (9), and for 1936 to 1951 inclusive (26). The similar figure has also been found for the county borough for 1936 to 1950 inclusive (5). This last figure is of course included in the national figures.

(*b*) The actual number (22) of cases of bladder tumour, alive or dead, "reported" from the hospitals of the county borough in the years 1936–50, where the patient or deceased at the time of the "report" was employed in an insurable (Unemployment Insurance Act Regulations) capacity in a rubber occupation, and was also normally resident within the county borough and employed therein. Since occupational histories could not be obtained for all cases "reported" this number may be a serious underestimate, but it cannot be an overestimate.

(*c*) The number (33) of cases found from national death certificates or "reported" where the deceased or patient was either a non-insurable rubber worker, a retired rubber worker, a rubber worker in a job not classified as a rubber occupation, or a person who had previously been employed as a rubber worker but who now had a different occupation.

In Table II the cases are arranged in chronological order of "reporting" or certification, and the category as described above to which they are allotted is designated by the letter *a*, *b*, or *c*.

(*ii*) Estimates of the insured male population engaged in the rubber occupations for each year. For England and Wales this is computed for the years 1921 to 1951 inclusive, and for the county borough for the years 1936 to 1950 inclusive. The estimates were made as follows:

(*a*) The basal figures used are the estimates of insured persons employed in the rubber industry mentioned above. The figures for 1949, 1950, and 1951 were multiplied by 0·89 to bring them into line with the pre-July 1948 figures, this being the date when the new National Insurance Act came into force. The factor 0·89 is the ratio of the June to July 1948 figures for the county borough, and the same factor is also used for the national figures in default of the June and July 1948 figures for England and Wales being available.

(*b*) The figures for 1921 and 1922 for England and Wales are taken as being the same as the figures for 1923, the first year for which the estimates are available.

(*c*) The figures thus obtained are now multiplied by a modifying factor which represents the ratio of males employed in the rubber occupations to those employed in the rubber industry. Managers are excluded. The figures could only be determined at three points, 1921, 1931, and 1951, the census years. No census was held in 1941 owing to the Second World War. The figures are respectively 0·57, 0·46, and 0·60. In each case these are derived from the information for England and Wales (or, in 1951, for Great Britain), and, in default of the specific figures being available, are regarded as being applicable to the county borough also. The 1921 figures

TABLE II

ALL WORKERS IN RUBBER OCCUPATIONS OR RUBBER INDUSTRY KNOWN TO HAVE HAD TUMOUR OF THE BLADDER

Date of "Report"	Index No.	Rubber Industry History (from all sources)	Age at Death	Age at "Report"	"Papilloma" P Carcinoma C	Category † *a*, *b*, or *c* (see text)	Within the County Borough
	1	Rubber worker	53	53	C	*a*	no
	2	Rubber works tyre dept	42	42	C	*a*	no
	3	Tyre cutter at rubber tube works	42	42	C	*a*	no
1921	4	Cutter in rubber hose pipe works	41	41	C	*a*	no
to	5	Labourer in electric cable works, rubber mix dept	69	69	C	*c*	no
1930	6	Rubber and leather manufacturer	68	68	C	*c*	no
	7	Rubber worker (retired)	70	70	C	*c*	yes
	8	Fabric preparing dept, tyre building factory 3 yrs	66	66	C	*a*	yes
	9	Mixer on rubber mill, tyre factory 5 yrs	58	58	C	*a*	yes
	10	Previously night watchman, rubber tyre factory	50	50	C	*c*	yes
	11	Foreman, rubber tyre factory	55	55	C	*a*	no
1931	12	Rubber worker	53	53	C	*a*	no
to	13	Rubber moulder	37	37	C	*a*	no
1935	14	Rubber worker (retired)	80	80	C	*c*	no
	15	Stoker, rubber factory	68	68	P	*c*	no
		Pivotal Point					
	16	Labourer, rubber works	77	77	C	*a*	no
	17	Foreman rubber worker, tyre factory	68	68	C	*a*	no
	18	Rubber hand	65	65	C	*a*	no
1936	19	Mechanical rubber worker	68	68	C	*a*	no
to	20	Rubber mixer	68	68	P	*a*	no
1940	21	Rubber worker, rubber mills	62	62	C	*a*	no
	22	Rubber worker (retired)	78	78	C	*c*	yes
	23	Air compressor attendant. Machine in tyre shed, rubber works, 23 yrs (retired)	—	67	P	*c*	yes
	24	Rubber mixer on mill, tyre factory 17 yrs	—	45	P	*b*	yes
	25	Previously labourer in rubber works, many yrs	—	61	P	*c*	no
	26	Foreman, rubber works	38	38	C	*a*	no
	27	Rubber worker	63	63	C	*a*	no
	28	Labourer, rubber works	63	63	C	*a*	no
	29	Labourer, rubber tyres	60	60	P	*a*	no
	30	Labourer, rubber works	65	65	C	*a*	no
	31	Rubber stamp manufacturer (retired)	72	72	C	*c*	no
	32	Manager, rubber works (retired)	71	71	C	*c*	no
1941	33	Labourer, rubber works (retired)	71	71	C	*c*	no
to	34	Foreman rubber worker (retired)	82	82	C	*c*	yes
1945	35	Mixer in rubber mill, tyre factory 20 yrs, death certificate gave only other causes	47	46	C	*b*	yes
	36	Tyre moulder 7 yrs, later tyre inspector (retired)	76	76	C	*c*	yes
	37	Rubber mixer, foreman, rubber mill 30 yrs	—	67	P	*b*	yes
	*38	Tube department, tyre factory 30 yrs	—	60	P	*b*	yes
	39	Foreman, tube dept, tyre factory 35 yrs	58	58	C	*a* and *b*	yes
	40	Rubber factory foreman, tyres, later soles, 22 yrs.	58	52	C	*a*	no
	41	Rubber tyre factory, 1912–15	—	56	P	*c*	yes
	42	Tyre factory, grinder in tool-room, 1920–30	54	53	C	*c*	yes
	43	Commissionaire, tyre factory, 1940–45	62	62	C	*c*	yes

TABLE II—*Continued*

ALL WORKERS IN RUBBER OCCUPATIONS OR RUBBER INDUSTRY KNOWN TO HAVE HAD TUMOUR OF THE BLADDER

Date of "Report"	Index No.	Rubber Industry History (from all sources)	Age at Death	Age at "Report"	"Papilloma" P Carcinoma C	Category † *a*, *b*, or *c* (see text)	Within the County Borough
	44	Rubber tyre worker	54	54	C	*a*	no
	45	Foreman, rubber tyre works	44	44	P	*a*	no
	46	Mat puncher, rubber mat manufacturers	65	65	C	*a*	no
	47	Labourer, motor tyre factory	44	44	C	*a*	no
	48	Rubber tyre maker's moulder	38	38	C	*a*	no
	49	Rubber worker	68	68	C	*a*	no
	50	Rubber pressman	66	66	C	*a*	no
	51	Ruber moulder	54	54	C	*a*	no
	52	Rubber hose cutter (retired)	75	75	C	*c*	no
	53	Rubber pressman (retired)	75	75	C	*c*	no
	54	Tyre builder, rubber works (retired)	76	76	C	*c*	no
	55	Rubber works, 1920–26	77	77	C	*c*	yes
1946	56	Rubber worker, 1919–24	—	54	P	*c*	no
to	57	Rubber mixer in mill 9 yrs	66	66	C	*a*	no
1951	58	Tyre cover maker 42 yrs	—	69	P	*b*	yes
(Eng-	59	Tyre moulder, many years	—	51	P	*b*	yes
land	60	Rubber worker, tyre factory 30 yrs	—	58	P	*b*	yes
and	61	Rubber moulder, tyre works 30 yrs	—	48	C	*b*	yes
Wales)	62	Rubber worker, tyre-works 37 yrs	—	57	P	*b*	yes
	63	Rubber moulder, tyre factory 2 yrs	—	49	P	*b*	yes
	64	Rubber worker, tyre factory 30 yrs	—	60	C	*b*	yes
	65	Rubber worker, tyre factory 13 yrs	—	33	C	*b*	yes
	66	Rubber moulder, tyre factory 29 yrs	—	59	P	*b*	yes
and	67	Rubber mill, mixer, tyre factory 28 yrs	—	55	C	*b*	yes
	68	Rubber moulder, tyre factory 38 yrs	59	59	C	*a* and *b*	yes
	69	Previously labourer in rubber works, many yrs	—	63	P	*c*	no
	70	Tube extruder, tyre factory 24 yrs	—	45	P	*b*	yes
	71	Rubber worker, rubber mill (retired at time of death but not of "report")	72	69	C	*b*	yes
1946	72	Rubber moulder, tyre factory, 1924–26	—	50	P	*c*	no
to	*73	Vulcanizer, tyre factory 33 yrs	—	58	C	*b*	yes
1950	74	Previously in elastic thread dept, rubber works 1 yr	—	27	P	*c*	yes
(Coun-	75	Rubber works labourer 30 yrs	62	62	C	*a* and *b*	yes
ty Bo-	76	Rubber moulder, tyre factory 27 yrs	51	51	C	*a* and *b*	yes
rough)	77	Rubber moulder, tyre factory, 1919–41	—	62	C	*c*	no
	78	Pipe fitter, 1929–41, tyre factory	67	66	P	*c*	yes
	79	Maintenance man, tyre factory, 1919–32	—	62	P	*c*	yes
	80	Engineer, mainly research and development, tyre and golf-ball factory, 1937–41	—	36	P	*c*	yes
	81	Works engineer, tyre factory	—	62	C	*c*	yes
	82	Pipe-fitter, 1918–22, tyre factory	—	67	P	*c*	yes
	83	Rubber moulder, 1940–41	—	54	P	*c*	yes
	84	Maintenance engineer, rubber works	68	68	C	*c*	no
	85	Rubber moulder, tyre factory 18 yrs	36	36	C	*a* and *b*	yes

*These two patients noted that several other men in the same department were suffering from the same complaint.

†Total Category *a*: 35; Total Category *b*: 22 (including five common to *a* and *b*); Total Category *c* (not used in statistical studies): 33.

are used for the decade 1921–30, the 1931 figures for the decade 1931–40, and the 1951 figures for the decade 1941–50, and also for the year 1951. The use of modifying factors derived at long intervals results in some discontinuity of trend, and it is unfortunate that the 1931 figure was obtained at a time of severe industrial depression. The original figures for insured workers in the rubber industry show a discontinuity between 1930 and 1931; this discontinuity is magnified by the change of the modifying factor from 0·57 to 0·46 at the end of the decade. The crude figures do not show a discontinuity between 1940 and 1941, though one is introduced by the change of the modifying factor in the rubber occupations figures. It is thus possible that towards the end of the decade 1931–40 the population at risk has been underestimated by as much as 24 per cent. However, since the expected number of death certificates for the rubber occupations in England and Wales at the risk current for the general population for the half decade 1936–40 is estimated as 2·7 on the figures used, the 24 per cent. underestimate would be only 0·65, and this amount would not affect the final conclusions.

The same discontinuity between 1940 and 1941 is introduced into the figures for the county borough, but the error which might be introduced by underestimation for the years 1936–40 would amount to 0·33 cases in the expected estimate, which could not affect the conclusions.

(*d*) The figures are now finally adjusted to age-specific figures. At the present stage of adjustment they are limited to men under 65. These figures are broken down into age groups by using the percentage age-distribution for 1921 for the decade 1921–30, 1931 for 1931–40, and 1951 for 1941–50, and also for 1951, the calculated proportion of men aged over 65 being added to the total figures. The national figures for England and Wales are used for the county borough in default of the specific figures being available. However, in 1921, when the county borough figures were available, they showed a very marked similarity to the national figures. The age distribution figures are shown in Table III.

It is recognized that this adjustment has followed a tenuous argument, and relies to some extent upon the demographic structural stability of the industry during each decade, and also upon the assumption that the part of the industry in the county borough is a reasonable cross section of the industry as a whole. Such published figures as are available suggest that in fact both these conditions obtain to such a degree that the estimates are sufficiently good for the present purpose. Could the estimates of the population at risk be shown to be sufficiently erroneous, and it is possible that data may later become available to enable the figures to be reviewed, then the statistical conclusions of these studies would be invalidated. Therefore the total finally adjusted figures for England and Wales are shown in full in Table IV. The figures for the county borough are not shown here but, as will be shown later, the discrepancy between the actual findings and the expected findings in this area are so great that it would seem unlikely that an error can have been introduced which would be sufficient to invalidate the conclusions referring to the county borough.

TABLE III

PER CENT. AGE DISTRIBUTION OF MALE WORKERS IN RUBBER OCCUPATIONS

Area	Year	Age					
		Under 25	25–	35–	45–	55–	65 and Over
England and Wales	1921	28·4	26·6	20·8	14·3	7·4	2·6
	1931	26·4	31·3	19·6	13·1	7·6	2·1
	1951	11·8	29·8	31·9	15·9	7·6	3·0
County Borough	1921	21·2	29·6	25·4	15·6	5·1	2·1

TABLE IV

ESTIMATED NUMBERS OF MALE WORKERS IN RUBBER OCCUPATIONS WHO WOULD HAVE BEEN INSURABLE UNDER PRE-1948 (UNEMPLOYMENT INSURANCE ACT) REGULATIONS, OR WHO WOULD HAVE BEEN DEBARRED FROM BEING INSURABLE SOLELY BECAUSE OF BEING OVER 65

England and Wales

Year	Number	Year	Number	Year	Number
1921	16,611	1931	15,379	1941	23,684
1922	16,611	1932	15,355	1942	19,306
1923	16,611	1933	15,819	1943	17,235
1924	16,979	1934	15,777	1944	18,205
1925	17,447	1935	16,759	1945	18,743
1926	17,488	1936	16,542	1946	23,892
1927	18,067	1937	16,693	1947	29,413
1928	19,043	1938	16,111	1948	31,658
1929	19,786	1939	17,280	1949	30,932
1930	20,213	1940	17,984	1950	33,171
				1951	36,261

(*iii*) The age-specific certification rates (*cf.* Case, 1953a) for males in England and Wales by decades from 1921–50. These are shown in Table V.

TABLE V

AGE-SPECIFIC CERTIFICATION RATES (PER MILLION LIVING PER YEAR) FOR MALE DEATH CERTIFICATES MENTIONING BLADDER TUMOUR, CALCULATED FROM DECENNIAL FIGURES, ENGLAND AND WALES

Age	Decennium		
	1921–30	1931–40	1941–50
Under 25 ..	0·38	0·22	0·26
25–	1·92	1·89	1·37
35–	10·66	10·61	11·10
45–	47·30	54·95	63·58
55–	160·67	166·86	210·24
60 and Over ..	445·12	477·36	562·41

(*iv*) The age-specific certification rates and "report" rates for the county borough for the years 1936–50. These have already been shown in Table I.

(*v*) The number of death certificates mentioning tumour of the bladder that would have been expected to occur in the populations at risk in England and Wales, and also in the county borough during the relevant periods had the disease occurred at the rate pertaining for the general male population of these areas respectively.

(*vi*) The number of cases of bladder tumour that would have been expected to have been "reported" from the hospitals of the county borough from the population at risk had the cases occurred at the rate pertaining for the general male population of the county borough.

Results

(1) England and Wales.—Table VI shows the number of bladder tumour death certificates found and expected for males in the rubber occupations in England and Wales during the periods 1921–35 and 1936–51. Since the numbers found can only be integers, it is assumed that sampling errors may be expected to conform to the Poisson distribution, and the significance of the difference on this hypothesis is shown. The figures are also expressed as a standardized mortality ratio (S.M.R.) in conformity with the practice of the Registrar General in the extract from the "Occupational Mortality Tables" quoted in the historical section. This S.M.R. is the number of deaths found per 100 deaths expected.

Table VI

COMPARISON OF THE NUMBER OF MALE DEATH CERTIFICATES MENTIONING TUMOUR OF THE BLADDER EXPECTED AND FOUND IN THE RUBBER OCCUPATIONS AS DEFINED FOR 1921–35 AND 1936–51, ENGLAND AND WALES

Period	1921–35		1936–51	
Number	Expected	Found	Expected	Found
	8·5	9	15·9	26
Standardized Mortality Ratio		106		164
Significance of Difference *P*	>·1		<·025	

Assuming the validity of the population at risk estimates, these figures must be interpreted as showing that an excess of deaths from bladder tumour has occurred in men engaged in rubber occupations in England and Wales during the period 1936–51, and that no such excess was demonstrable in the period 1921–35. This excess is statistically significant.

(2) The County Borough

(*a*) *Death Certificates.*—Table VII shows the number of bladder tumour death certificates found and expected for males in rubber occupations in the county borough during the period 1936–50. The significance of the difference and the S.M.R. are also shown. Although the S.M.R. is higher than the national figure for 1936–51, the small number of cases concerned is too small for the difference between the numbers found and expected to be regarded as statistically significant.

Table VII

A COMPARISON OF THE NUMBER OF DEATH CERTIFICATES MENTIONING TUMOUR OF THE BLADDER EXPECTED AND FOUND IN THE RUBBER OCCUPATIONS AS DEFINED FOR THE YEARS 1936–50

Males. The County Borough

Number	Expected	Found
	2·6	5
Standardized Mortality Ratio		192
Significance of Difference, *P*	·1	

(*b*) *Hospital "Reports".*—Table VIII shows the number of cases, alive or dead, found and expected in the hospital "reports" for males engaged in the rubber occupations in the county borough during the years 1936–50. The significance of the difference and the standardized "report" ratio (S.R.R.) is shown. The standardized "report" ratio is used in the same way as, and with a homologous meaning to, the S.M.R. Again assuming the validity of the estimates of the population at risk, and also that the "report" rates are not seriously underestimated, these figures must be interpreted as showing a gross excess of cases of bladder tumour found over cases

Table VIII

A COMPARISON OF THE NUMBER OF "REPORTED" CASES OF BLADDER TUMOUR EXPECTED AND FOUND IN THE RUBBER OCCUPATIONS AS DEFINED FOR THE YEARS 1936–50

Males. The County Borough

Number	Expected	Found
	4·0	22
Standardized Mortality Ratio		550
Significance of Difference *P*	<·001	

expected. It seems an extremely remote possibility that the errors in forming the estimate of the expected number could be sufficiently great to invalidate the result, since the figure for the estimate would have to be increased to about fifteen, *i.e.* to nearly four times its present value, before the difference between the expected number and the number found would cease to be statistically significant. This would imply that, even if the number of workers in the rubber occupations equalled the figures given for the rubber industry (the limiting case), then the hospital "reports" would have to be less than 50 per cent. of the true incidence for the area, and further would have to be so biased that all the rubber worker cases were included in the 50 per cent. that were in fact "reported"! There is no reason to believe that any such bias for rubber cases being "reported" would exist, and, as was mentioned previously, the figure of 22 cases found is likely to be an underestimate because of the number of hospital "reports" where no occupation is known.

It would thus seem that the statement that there is a definite excess of cases of bladder tumour in workers in the rubber occupations in the county borough can be made with considerable confidence.

Discussion

This investigation was undertaken with a specific object in view, to see whether the introduction of a certain rubber antioxidant into the rubber industry could have given rise to an industrial hazard of occupational tumour of the urinary bladder. On the hypothesis that it had done so, and that no such risk had been present before, or had been introduced contemporaneously, it would be expected that no risk could be demonstrated before a date about 10 years after the introduction of the hazard, that the national figures might show the presence of a risk subsequently to this, and that this risk would persist or be enhanced in areas where the particular substance had been used, since, being a substance not unique in its industrial properties, and manufactured only by certain firms, there would be no reason to expect its use to be evenly spread throughout the country. The results obtained—that a risk is demonstrable in the national figures (deaths only) since a date about 7 years after the introduction of the particular antioxidant into the rubber industry, and that this risk persists (live and dead cases) and is in fact enhanced in an area where the substance was known to have been used—are compatible with the truth of the hypothesis, but they are in no sense a proof of its truth. Many critical factors have not been examined because the data required for their examination were not available. For instance, it would be essential for the acceptance of the hypothesis to show that no risk had appeared in areas of the rubber industry where the particular substance had never been introduced, and it would be desirable to find exactly what processes were affected in the areas where it had.

It is perhaps apposite to quote the words of Anscombe (1951):

> It is worthwhile to distinguish the different purposes one may have in accepting a hypothesis: (*i*) to base an administrative decision on, (*ii*) for further testing and confirmation, (*iii*) for acceptance into the corpus of scientific knowledge, to be relied on in future work.

In the present case, it is not suggested that the hypothesis should be accepted for purpose (*iii*); it is suggested that it could be regarded as sufficiently acceptable on the evidence produced to form a basis for planning an investigation under heading (*ii*), and that until this investigation has been planned and executed it should be accepted as sufficiently true for certain decisions under heading (*i*).

A word of caution is necessary about the possible extrapolation of the results reported herein. The substance considered was manufactured in Great Britain by a process that left some uncombined amine in the finished product. Methods of manufacture used elsewhere may not leave this uncombined fraction. The results reported here apply to England and Wales and to a county borough situated in one of these countries. It does not follow, therefore, that the hazard shown by these studies will necessarily exist elsewhere, and negative findings in other countries should not be regarded as invalidating these results.

Leaving, for a moment, the statistical considerations which have been the subject of this paper so far, and considering the 85 cases listed in Table II, of which only 52 can be used in the statistical section, it is worthwhile noting that cases have occurred in workers employed in care and maintenance work and in jobs that would bring them into considerable contact with departments where rubber occupation proper would be pursued (*e.g.*, an air-compressor attendant who worked a machine for many years while it was situated in a tyre manufacturing department). Whilst of course no evidence has been presented that all or any of these tumours amongst these ancillary workers are of occupational origin, it should be remembered that cases which were regarded as occupational were noted in workers in ancillary jobs of a like nature in the survey of a section of the chemical industry (Case and others, 1954).

Furthermore, in the county borough, forty patients worked or had worked in one factory, and two letters received from rubber workers in answer to the questionary mentioned that the sender had thought it remarkable that several men (five and seven were quoted, six were traced) working in the patient's own particular shed were attending hospital for treatment for the same complaint (these two observations referred to the same shed and the same men). This number is greater than the number of cases expected for the whole county borough. These observations suggest that there may be local areas of risk where the incidence is raised further above the expected level than is suggested by the overall figures. This phenomenon of a very high risk around the actual dangerous process was noted by Hueper (1948) as one of the criteria of environmental hazard, and further detailed investigation might well show this type of incidence to be present in the rubber industry.

Another feature of Table II is the number of patients still alive. Unless it is postulated that the occupational cases tend to have a longer survival time than the non-occupational ones, a phenomenon not reported by Case and others (1954), for the chemical industry, this would suggest that the outbreak of occupational tumour of the bladder in rubber workers has been noted in an early stage. If the causal agent can be located with certainty, and either removed or its effects prevented, then the outbreak may never assume the serious proportions that might otherwise follow.

Since insufficient evidence exists as yet to distinguish the occupational cases from the non-occupational ones in Table II, no studies have been attempted in relation to the induction time of the occupational disease within the rubber industry, and no attention has been paid to the age at onset or at death.

Summary and Conclusions

(1) There seems to be reasonably good statistical evidence for saying that, in the period between 1936 and 1951, an occupational risk of dying of bladder tumour can be demonstrated amongst males in England and Wales who are employed in the rubber occupations as defined by the "1931 Census Reports, Occupation Tables" (General Register Office, 1934).

(2) There is even better statistical evidence for saying that in a certain county borough, which is an important centre of the rubber industry, there is an occupational risk of contracting bladder tumour amongst males so employed. This evidence covers the years 1936–50.

(3) There is no statistical evidence even to suggest that such an occupational risk of dying of bladder tumour was operating amongst males in these occupations in England and Wales in the period 1921–35.

(4) These findings are consistent with, but do not prove, the hypothesis that the risk was introduced into the industry with a certain antioxidant in 1928. This antioxidant was used in the rubber industry in the county borough studied. It was known to have caused bladder tumours amongst men in the chemical industry who manufactured it. The antioxidant concerned, as manufactured in Britain, contained about 2·5 per cent. of free naphthylamine, including a proportion of both the alpha and beta isomers, and it is known that the treatment accorded to the rubber "mix" containing the antioxidant volatilizes quantities of naphthylamines.

(5) When the trend of these studies became known, the manufacturers of the antioxidant voluntarily ceased its manufacture and withdrew it from their range of products, and the rubber industry immediately discontinued the use of the antioxidant and destroyed old stocks.

(6) Cases of bladder tumour have also been noted in fitters, engineers, and others in ancillary jobs in the rubber industry who might be expected to have intermittent contact with contaminated machinery. No statistical data are available to enable an opinion to be formed about the possible occupational origin of these cases.

It would be a pleasure to acknowledge individually and by name the many people in the hospitals and the rubber industry in the county borough, on whose close co-operation the success of much of the investigation depended. Since the county borough has remained anonymous, we have not done this; but we hope that these invaluable helpers will recognize themselves and accept our sincere thanks for untold hard work, assistance, and encouragement.

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SOME ASPECTS OF BREAST-FEEDING IN BELFAST

BY

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Purpose of the Inquiry

The object of this survey was the comparison of the "incidence" of breast feeding among mothers confined at the Royal Maternity Hospital, Belfast, with that among mothers confined elsewhere in the city. The data were collected in such a way that this comparison was possible at various ages of the infant up to a maximum of 6 months. Information was collected about factors likely to influence breast feeding so that, where necessary, allowance could be made for them.

The inquiry was not concerned with the advantages or disadvantages of breast feeding and no attempt has been made to compare breast-fed with artificially-fed children. There is already a large literature on these particular aspects of infant feeding (*e.g.* Gairdner, 1945; Cruickshank, 1945; Stevenson, 1947; Stewart and Westropp, 1953) and, though improvements in feeding techniques and quality of artificial foods, coupled with an increased awareness of the value of adequate vitamin supplements, has tended to minimize the differences in health experienced by infants fed in different ways, it remains true that the easiest method of feeding a baby properly is on the breast, providing breast feeding is correctly and successfully established.

The Data

The inquiry was limited to mothers who had their babies between September 1 and November 30, 1951, and who were normally resident in the County Borough of Belfast. In the 3 months there were 279 live births to such mothers in the Royal Maternity Hospital. Each birth was identified on the notification of births register maintained by the Belfast Health Committee, and the next live birth on the register was selected as a member of a control group. With this method of selection it is reasonable to assume that the Control group was representative of births to Belfast mothers, exclusive of those confined in the Royal Maternity Hospital, during the 3-months period.

Each mother was visited monthly by a health visitor until her infant reached the age of 6 months or until breast feeding was stopped, whichever was the earlier. For this purpose the end of breast feeding implied that the child was not receiving breast milk at all.

Multiple births were excluded from the analysis because of the special feeding problems involved; this reduced the size of the groups by sixteen in the Royal Maternity Hospital group (R.M.H.) and by twelve in the Control group. For various reasons it was found impossible to observe 21 children in the R.M.H. group and nine in the Control group for the complete period required and these are also excluded. The reasons for the exclusions are given in Table I, and it is unlikely that the omissions will materially affect the results; only in the lack of co-operation was there any great difference between the two groups as seven of the eight mothers concerned were members of the R.M.H. group.

TABLE I

COMPOSITION OF SAMPLES

Description		Source of Subjects: Royal Maternity Hospital, Belfast (R.M.H. Group)		Source of Subjects: Belfast C.B. Birth Notification Register (Control Group)	
Infants followed for first 6 months of life			242		258
Infants not followed	Mother died	1	21	—	9
	Infant died	5		3	
	Family moved from Belfast	8		5	
	Mother would not co-operate	7		1	
Multiple births omitted			16		12
Original number of R.M.H. or Control births obtained from source			279		279

Information obtained from birth records, or from each mother, made it possible further to subdivide each group according to the following factors:

(1) Age of mother,
(2) Sex of infant,
(3) Parity of infant,
(4) Birth weight of infant,
(5) Type of ante-natal care received.

Moreover the Control group could be subdivided according to place of confinement.

Any defined group or sub-group of children could, from the data collected, be distributed according to three "methods" of feeding at various ages throughout the first 6 months of life. In what follows the three feeding methods are shown as:

"B" entirely breast-fed

"B+" breast-fed, but supplemented with artificial and/or solid food

"NB" not breast-fed, *i.e.* fed on artificial and/or solid food.

In the Tables the ages at which the distributions are shown are restricted to "Birth" (0 weeks), and the exact ages of 1, 2, 3, 4, 8, 12, 16, 20, and 24 weeks. In this context the relevant feeding recorded at "Birth" was that which constituted the major part of feeding during the first 48 hours.

Results

In Table II the percentages of the 242 infants in the R.M.H. group and of the 258 infants in the Control group in each feeding category are shown. At most ages the R.M.H. and Control distributions are similar. The greatest discrepancy is likely to occur by chance more than once in twenty times, the conventional level of "significance" adopted in this report.†

Table II

PERCENTAGE DISTRIBUTIONS OF INFANTS IN R.M.H. AND CONTROL GROUPS, BY METHOD OF FEEDING AT VARIOUS AGES*

Age (wks)	R.M.H. Group (242 infants)			Control Group (258 infants)			Comparison between Absolute Distributions		
	B	B+	NB	B	B+	NB	χ^2	n	P
0	90·9	—	9·1	89·9	—	10·1	0·05	1	0·80 – 0·90
1	75·6	12·8	11·6	77·1	10·1	12·8	1·01	2	0·50 – 0·70
2	65·7	16·5	17·8	63·2	15·5	21·3	1·01	2	0·50 – 0·70
3	59·5	16·5	24·0	57·0	12·0	31·0	4·17	2	0·10 – 0·20
4	52·1	15·3	32·6	47·7	15·5	36·8	1·11	2	0·50 – 0·70
8	36·4	10·7	52·9	30·2	17·4	52·3	5·37	2	0·05 – 0·10
12	24·8	11·2	64·0	21·7	15·9	62·4	2·62	2	0·20 – 0·30
16	17·4	10·7	71·9	17·8	11·2	70·9	0·06	2	0·95 – 0·98
20	12·0	9·5	78·5	12·4	11·2	76·4	0·46	2	0·70 – 0·80
24	4·1	14·5	81·4	7·0	12·0	81·0	2·37	2	0·30 – 0·50

* In this and subsequent Tables, the distribution at 0 weeks of age gives percentage of infants in each feeding group at start of feeding. Distributions at 1, 2, etc. weeks show positions on 7th, 14th, etc. day. "B" indicates breast feeding only; "B+" indicates breast feeding plus bottle and/or solid feeding; "NB" indicates bottle and/or solid feeding.

It might be argued that although no apparent difference is revealed when the two groups are compared, a real difference might emerge if a comparison were made of children of like parity, sex, and age of mother. It has been suggested that these factors influence breast feeding and that consequently any comparison between groups of infants should take account of these factors if they themselves differ between the compared groups. It seemed likely that the R.M.H. group would comprise a preponderance of first births to relatively young mothers in contrast to the Control group which included domiciliary births with a preponderance of second or later births to older mothers.

In fact nearly three-quarters (71 per cent.) of the R.M.H. group were first-born children compared with less than one-quarter (24 per cent.) of the Control group. A comparison of the complete parity distribution between R.M.H. and Control groups reveals a highly significant difference ($\chi^2 = 116{\cdot}45$, $n = 7$, $P < 0{\cdot}001$). The average age of the mothers of the R.M.H. group was 27·65 years, compared with 29·04 for the Control group; the distributions into six 5-year age groups differ significantly ($\chi^2 = 15{\cdot}53$, $n = 5$, $0{\cdot}01 > P > 0{\cdot}001$).

There was no material difference in the sex ratio of the R.M.H. and Control children. The sex distributions do not differ significantly, 56 per cent. of all the children were boys ($\chi^2 = 0{\cdot}07$, $n = 1$, $0{\cdot}80 > P > 0{\cdot}70$).

Two other factors might influence the comparison of feeding practices between the two groups. A difference in the proportion of premature infants would have demanded a difference in amount and skill of nursing attention, and a difference in the amount and type of ante-natal instruction might have influenced the mothers differently in their attempts to establish and maintain breast feeding.

On the first point it is to be noted that of the 242 R.M.H. infants, 17 were premature by the $5\frac{1}{2}$-lb. weight criterion compared with nine of the 258 Control children; the difference is not significant ($\chi^2 = 2{\cdot}49$, $n = 1$, $0{\cdot}20 > P > 0{\cdot}10$) and any influence this factor might have on the present results may be ignored.

The aspect of ante-natal care, however, is not so easily dismissed. Table III (opposite) shows how the ante-natal care was obtained; any attendance which resulted in less than two visits to the responsible centre, clinic, or surgery, has been omitted in compiling this Table. Nearly all the R.M.H. mothers attended the Hospital clinic in the ante-natal period, only 21 (8·6 per cent.) did not attend at least twice. The majority of the control mothers were attended by their general practitioners during the ante-natal months, and 62·4 per cent. of them attended their own doctor to the exclusion of all other services.

† It should be noted that, for the comparison of percentages in any single feeding category of the order of 50 per cent., minimum differences between the R.M.H. and Control groups of about 9 per cent. would be required to indicate "significance" by this criterion, while the smallest significant difference would be about 5 per cent. for percentages of the order of 90 or 10 per cent.

TABLE III

DISTRIBUTION OF INFANTS IN R.M.H. AND CONTROL GROUPS, BY TYPE OF ANTE-NATAL CARE RECEIVED BY MOTHERS

Ante-Natal Care of Mother	R.M.H. Group			Control Group		
	No.	Per cent.		No.	Per cent.	
Hospital clinic only	205	84·7	85·1	53	20·5	21·7
Hospital and midwife	1	0·4		—	—	
Hospital and public health clinic	—	—		3	1·2	
G.P. only	18	7·4	13·6	161	62·4	68·2
G.P. and hospital clinic	15	6·2		4	1·6	
G.P. and public health clinic	—	—		3	1·2	
G.P. and midwife	—	—		8	3·1	
Public health clinic only	3	1·2	1·2	25	9·7	10·1
None	—	—		1	0·4	
Total	242	100		258	100	

From bracketed groups $\chi^2 = 201{\cdot}66$, $n = 2$, $P < 0{\cdot}001$

Probably the best arrangement of the data that can be made for comparing the types of ante-natal care between the R.M.H. and Control groups is that shown by the bracketed distributions in Table III; this suggests that the difference between the two groups in respect of type of ante-natal care, and therefore possibly of type of instruction about feeding, is quite considerable ($\chi^2 = 201{\cdot}66$, $n = 2$, $P < 0{\cdot}001$).

It would therefore appear that if parity, age of mother, and type of ante-natal care, do have an effect on the subsequent feeding habits of the children, then a legitimate comparison of the feeding methods employed by the R.M.H. and Control groups must take these factors into account. The data are not sufficiently numerous to examine properly the influence of each of these factors separately, or to permit a limitation of the comparison between the R.M.H. and the Control groups to sub-groups of children of similar parity, age of mother, and ante-natal care. After a rigorous examination of the available data the impression is left that in the R.M.H. group, after the first few weeks of life, there was a tendency for the second- or later-born children to include a greater number who were breast-fed than the first-born, and for younger mothers to breast-feed more commonly than older mothers. But neither of these tendencies is well defined or significant in the conventional sense, and in the Control group the age-of-mother influence appeared to act in the opposite direction as the children became older. It is stressed that these comments are essentially tentative and that none of the apparent differences is statistically significant; these remarks are recorded merely as points of interest which may be worthy of more detailed study with larger numbers of infants.

The possibility of such tendencies existing, coupled with the results of work done elsewhere (Hughes, 1942; Dummer, 1949; Douglas, 1950; Westropp, 1953), necessitates some form of treatment of Table II to eliminate from the comparison any possible influence of the different constitution of the R.M.H. and Control groups in respect of concomitant factors. To this end, each of the three factors was divided into two sub-groups; age of mother was split into "under 30" and "30 and over", parity into "first-born" and "second- and later-born", and ante-natal care into the first three categories combined of Table III and the remainder. This arrangement results in eight different combinations of sub-groups of the three factors by which a mother and child can be classified. For simplicity in subsequent discussion the combinations are described as "age-parity-care groups". The members of the R.M.H. group and Control group were distributed into these eight groups, and for each, at each tabulated age of infant, for the pooled data of 500 observations, the proportion of children in each of the feeding categories, B, B+, and NB, was estimated. These proportions were then applied to the numbers of children in the R.M.H. group at the corresponding age of infant and "age-parity-care" group, to give the number of children "expected" in each feeding category. The total expectation in each feeding group at each age of infant was found by summing the expected numbers in the eight "age-parity-care" groups. Thus for any age of infant the "expected" numbers give a distribution by feeding category based on the hypothesis that the R.M.H. children were distributed in the feeding categories in the same proportions as all children surveyed, appropriate allowance having been made for their parity, the age of their mothers and the type of ante-natal care the latter received. A similar series of calculations was then followed for the Control group.

The results of this procedure are shown in Table IV (overleaf) where the observed numbers in each feeding category are shown as percentages of the expected numbers. None of these departs widely from 100 per cent., which indicates the similarity between the observed and expected distributions. Since the latter are based on a null hypothesis it follows that the similarity between the observed results (Table II) is unlikely to be explained by the differences in parity, age of mother, and type of ante-natal care observed between the R.M.H. and Control groups. In fact the results of the process of standardization adopted suggest that the practice of feeding during the first 6 months of the child's life is even more similar in the R.M.H. and Control groups than the crude figures of Table II suggest.

TABLE IV

DISTRIBUTION OF INFANTS IN R.M.H. AND CONTROL GROUPS BY METHOD OF FEEDING COMPARED WITH DISTRIBUTIONS EXPECTED ON THE HYPOTHESIS THAT NO DIFFERENCE EXISTS BETWEEN THE TWO GROUPS AFTER ALLOWANCE FOR DIFFERENCES IN AGE OF MOTHER, PARITY, AND TYPE OF ANTE-NATAL CARE

(Observed numbers shown as percentages of expected)

Age (wks)	R.M.H. Group (242 infants)			Control Group (258 infants)			Comparison between Absolute Distributions		
	B	B+	NB	B	B+	NB	χ^2	n	P
0	99·4	—	106·2	100·6	—	95·3	0·16	1	0·50 — 0·70
1	97·5	114·8	102·9	102·5	86·7	97·7	1·40	2	0·30 — 0·50
2	98·9	102·0	102·5	101·1	98·1	98·1	0·12	2	0·90 — 0·95
3	99·4	111·7	94·7	100·6	88·1	104·2	1·31	2	0·50 — 0·70
4	101·7	97·8	98·4	98·3	102·1	101·3	0·14	2	0·90 — 0·95
8	105·5	83·2	100·5	94·4	113·2	99·5	2·10	2	0·30 — 0·50
12	102·2	94·0	100·3	97·7	104·4	99·7	0·24	2	0·80 — 0·90
16	98·4	100·4	100·3	101·5	99·6	99·7	0·02	2	0·98 — 0·99
20	104·1	90·6	100·7	96·6	109·0	99·4	0·55	2	0·70 — 0·80
24	79·6	99·9	101·4	116·6	100·1	98·8	1·02	2	0·50 — 0·70

The greatest divergence between observation and expectation in Table IV occurs at 8 weeks of age and here the observed discrepancies or greater could have occurred by chance at least as often as three in ten trials.

Many suggestions have been made that establishing and maintaining breast feeding is more successfully carried out in the higher than in the lower social classes (Royal College of Obstetricians and Gynaecologists, 1948; Gordon, 1942; Douglas, 1950; Stewart and Westropp, 1953). Unfortunately no efficient index of social or economic status could be devised for the small number of mothers in the present survey, and it has not then been possible to take this factor into account. There is no reason to suppose, however, that the social status of the R.M.H. group differs in any marked degree from that of the Control group.

It will be appreciated that the method of selection of the members of the Control group resulted in including in that group children who were born in hospitals other than the Royal Maternity, in nursing homes, and in the mothers' own homes. Within the Control group a further possible source of variation can be examined, and although the proportion of hospital births in the Control group is small (30·2 per cent., compared with 58·6 per cent. births at home and 11·2 in nursing homes) it is possible that this small proportion does tend to make the Control group resemble the R.M.H. group rather more than a Control group selected entirely from non-hospital births would have done.

An examination was therefore made of three sub-groups of the Control group defined according to the actual place of confinement: hospital, nursing home, or home. The analysis, following the same pattern as that already used in the comparison between R.M.H. and Control groups, is presented in Tables V and VI (opposite). The tests of significance are complicated by the small number of nursing-home births; consequently for each age two tests are shown, the first compares the feeding distributions of hospital births with those of all others and the second compares domiciliary births with all others.

At each age the distributions are very similar (Table V) and at no age is the discrepancy greater than could easily have occurred by chance. Although not significant by the adopted criterion, it does appear that infants who were delivered in their own homes received supplements at a rather earlier age than others, but greater numbers are required for a proper examination. When allowance is made for the factors of age of mother, parity, and type of ante-natal care as before, the observed and expected distributions show very good agreement and this is particularly marked in the first month of life (Table VI). The rather high ratios of observed to expected which appear in the nursing-home group are almost certainly attributable to the small numbers involved, and owing to the size of the sampling errors it is clear that the present data are unlikely to reveal a very reliable picture of breast feeding by mothers confined in nursing homes.

Within the limits of the factors examined in this paper, the difference in the subsequent feeding practice of mothers who have their babies in the Royal Maternity Hospital and those who are confined elsewhere is not very great. With the samples which we have used we have been unable to detect any statistically significant difference in the proportions breast-fed, breast-fed with supplements and fed by bottle and/or solids at any age up to 6 months between children born in the Royal Maternity Hospital and those born elsewhere. It is therefore reasonable to pool the two groups of

TABLE V

PERCENTAGE DISTRIBUTION OF INFANTS BY METHODS OF FEEDING AT VARIOUS AGES IN SUB-GROUPS OF THE CONTROL GROUP CLASSIFIED BY PLACE OF CONFINEMENT

Age (wks)	Place of Confinement	Method of Feeding			Comparison between Absolute distributions		
		B	B+	NB	χ^2	n	P
0	Hospital ..	94·9	—	5·1	3·02	1	0·05 – 0·10
	Home	88·1	—	11·9	1·36	1	0·20 – 0·30
	Nursing Home	86·2	—	13·8			
1	Hospital ..	84·6	7·7	7·7	3·71	2	0·10 – 0·20
	Home	72·8	11·9	15·2	3·79	2	0·10 – 0·20
	Nursing Home	79·3	6·9	13·8			
2	Hospital ..	67·9	14·1	17·9	1·14	2	0·50 – 0·70
	Home	58·3	17·2	24·5	3·81	2	0·10 – 0·20
	Nursing Home	75·9	10·3	13·8			
3	Hospital ..	55·1	9·0	35·9	1·79	2	0·30 – 0·50
	Home	55·0	14·6	30·5	2·27	2	0·30 – 0·50
	Nursing Home	72·4	6·9	20·7			
4	Hospital ..	47·4	12·8	39·7	0·78	2	0·50 – 0·70
	Home	47·0	17·2	35·8	0·83	2	0·50 – 0·70
	Nursing Home	51·7	13·8	34·5			
8	Hospital ..	35·9	14·1	50·0	2·02	2	0·30 – 0·50
	Home	26·5	19·9	53·6	3·04	2	0·20 – 0·30
	Nursing Home	34·5	13·8	51·7			
12	Hospital ..	28·2	12·8	59·0	3·05	2	0·20 – 0·30
	Home	17·2	18·5	64·2	5·18	2	0·05 – 0·10
	Nursing Home	27·6	10·3	62·1			
16	Hospital ..	21·8	11·5	66·7	1·28	2	0·50 – 0·70
	Home	14·6	12·6	72·8	2·94	2	0·20 – 0·30
	Nursing Home	24·1	3·4	72·4			
20	Hospital ..	15·4	12·8	71·8	1·35	2	0·50 – 0·70
	Home	9·9	10·6	79·5	2·39	2	0·30 – 0·50
	Nursing Home	17·2	10·3	72·4			
24	Hospital ..	7·7	15·4	76·9	1·37	2	0·50 – 0·70
	Home	5·3	9·9	84·8	3·42	2	0·10 – 0·20
	Nursing Home	13·8	13·8	72·4			

At each age the percentages are based on the following numbers of infants:

Hospital 78
Home 151
Nursing Home .. 29

For each age the first χ^2 value refers to a test between "Hospital" and "Home and Nursing Home Combined", and the second χ^2 value to a test between "Home" and "Hospital and Nursing Home Combined".

TABLE VII

ACTUAL AND PERCENTAGE DISTRIBUTION OF INFANTS IN R.M.H. AND CONTROL GROUPS COMBINED BY METHOD OF FEEDING AT VARIOUS AGES

Age (wks)	Number			Percentage of Total (500) at Each Age			Standard Error of Percentage		
	B	B+	NB	B	B+	NB	B	B+	NB
0	452	—	48	90·4	—	9·6	1·32	—	1·32
1	382	57	61	76·4	11·4	12·2	1·90	1·42	1·46
2	322	80	98	64·4	16·0	19·6	2·14	1·66	1·78
3	291	71	138	58·2	14·2	27·6	2·21	1·56	2·00
4	249	77	174	49·8	15·4	34·8	2·24	1·62	2·13
8	166	71	263	33·2	14·2	52·6	2·11	1·56	2·23
12	116	68	316	23·2	13·6	63·2	1·89	1·53	2·16
16	88	55	357	17·6	11·0	71·4	1·71	1·40	2·02
20	61	52	387	12·2	10·4	77·4	1·46	1·37	1·87
24	28	66	406	5·6	13·2	81·2	1·03	1·52	1·75

TABLE VI

DISTRIBUTION OF INFANTS IN "PLACE OF CONFINEMENT" SUB-GROUPS OF THE CONTROL GROUP BY METHOD OF FEEDING COMPARED WITH DISTRIBUTIONS EXPECTED ON THE HYPOTHESIS THAT NO DIFFERENCE EXISTS BETWEEN THE THREE SUB-GROUPS AFTER ALLOWANCE FOR DIFFERENCES IN AGE OF MOTHER, PARITY, AND TYPE OF ANTE-NATAL CARE

(Observed numbers shown as percentages of expected numbers)

Age (wks)	Place of Confinement	Method of Feeding			Comparison between Absolute Distributions		
		B	B+	NB	χ^2	n	P
0	Hospital	102·2	—	71·7	0·62	1	0·30 – 0·50
	Home	100·0	—	99·7	0·0004	1	0·98 – 0·99
	Nursing Home	93·9	—	168·8			
1	Hospital	103·3	96·8	75·9	0·71	2	0·70 – 0·80
	Home	98·1	104·9	106·1	0·45	2	0·70 – 0·80
	Nursing Home	100·3	75·8	116·6			
2	Hospital	100·9	100·0	96·7	0·03	2	0·98 – 0·99
	Home	96·0	105·0	107·1	0·96	2	0·50 – 0·70
	Nursing Home	117·0	70·9	67·0			
3	Hospital	93·1	100·4	112·7	0·90	2	0·50 – 0·70
	Home	99·0	104·2	99·9	0·14	2	0·90 – 0·95
	Nursing Home	123·5	68·7	66·0			
4	Hospital	100·5	96·8	100·4	0·02	2	0·99 – 1·00
	Home	97·9	100·9	102·4	0·15	2	0·90 – 0·95
	Nursing Home	109·4	102·6	87·8			
8	Hospital	119·2	84·5	94·0	1·90	2	0·30 – 0·50
	Home	87·4	108·4	104·4	2·62	2	0·20 – 0·30
	Nursing Home	114·4	93·0	93·9			
12	Hospital	118·6	100·2	93·0	1·31	2	0·50 – 0·70
	Home	84·3	102·3	104·6	2·21	2	0·30 – 0·50
	Nursing Home	121·4	82·4	95·8			
16	Hospital	118·7	105·4	94·3	1·02	2	0·50 – 0·70
	Home	82·8	109·4	102·7	2·43	2	0·20 – 0·30
	Nursing Home	136·7	32·4	101·1			
20	Hospital	126·3	117·9	93·3	1·71	2	0·30 – 0·50
	Home	77·7	93·1	104·8	3·24	2	0·10 – 0·20
	Nursing Home	156·3	90·1	93·5			
24	Hospital	104·2	120·4	96·4	0·74	2	0·50 – 0·70
	Home	75·8	87·6	103·8	2·51	2	0·20 – 0·30
	Nursing Home	236·7	102·3	89·7			

The numbers of infants in the sub-groups are as follows:

Hospital 78
Home 151
Nursing Home .. 29

For each age the first χ^2 value refers to a test between "Hospital" and "Home and Nursing Home Combined", and the second χ^2 value to a test between "Home" and "Hospital and Nursing Home Combined".

births to obtain one distribution which gives a reasonable description of baby-feeding methods for the city as a whole (Table VII).

From the first week of life to the 24th the proportion of children in the group "breast-fed with supplements" varies very little and appears to amount to between 10 and 16 per cent. of all live

births. The decline in the proportions solely breast-fed as age advances is evident from Table VII. The salient features of these trends would appear to be:

(*a*) About one in every ten children born alive is never breast-fed.

(*b*) At the end of the first week of life about three-quarters of infants are fed solely on the breast while about one-eighth have breast milk and supplements and one-eighth have only artificial foods.

(*c*) At the end of the first month of life only 50 per cent. of children are solely breast-fed, and just over one-third have ceased to have breast milk.

(*d*) At the end of 2 months these proportions are reversed: one-third are solely breast-fed and one-half have ceased to be fed from the breast.

(*e*) At the end of 6 months about 80 per cent. of all infants are weaned and only 5 per cent. are existing entirely on breast milk.

Comparison with Other Studies

Although a large literature exists in which estimates of proportions of breast-fed children at various ages are featured, many difficulties arise in comparing these estimates between different surveys. These difficulties arise because of a lack of uniformity in sources of data, methods of sampling, methods of reporting results, criteria of breast feeding, and allowance for relevant concomitant factors. Most surveys are limited to the retrospective consideration of case histories which have accumulated in the clinics of local authorities, or in hospitals, or in general practice; only a few surveys have reported the results of oberving a group of infants from birth. Most are based on the experience of "all available records", and rarely has recourse been made to complete groups of scientifically drawn samples. The ages at which estimates are given vary considerably and are sometimes only approximate. Most reports make no distinction between babies fed solely on the breast and those in whom breast feeding is supplemented by other diet. Allowance for factors likely to influence the results, where such allowance is made, usually limits the data to certain defined groups according to the types of birth concerned.

Nevertheless it seems desirable to have on record the Belfast results side by side with those of surveys which appear to be based on reasonable data, but in interpreting the inevitable comparisons considerable caution must be exercised because of the general lack of uniformity. In Table VIII (opposite), the results of the Belfast survey are shown with those of other surveys. The Table is limited to three approximate ages corresponding to the end of the first, third, and sixth months of life. The proportions of babies in the feeding groups corresponding to the present Group B (solely breast-fed) and the combined group B and B+ (breast-fed with or without supplements) are shown, where available, for these ages.

The details of the other work shown in Table VIII cannot be given here although some indication is given of the size of the survey and the type of data used, in the remarks column. It should be noted, however, that for Hofmeier and Noack (1942) their best results are tabulated; for Norval (1947) the average of her town and country results is given; for Kollmann (1940) the average of hospital and home births is shown. From the present investigation, and indeed from most reports, it is evident that there is little use in quoting the proportion of breast-fed children at the time of discharge from a hospital. Such estimates appear to bear little relationship to those obtaining at later ages, and it is a common finding that mothers will breast-feed their infants while in hospital, either because they know that it is expected or because they wish to avoid argument, although they have every intention of weaning their infants as soon as possible after discharge. Breast-feeding for a few days such as results from this, can be of little value to the child, and it may be a danger as the mother may wean the child to an unsuitable diet in the absence of medical advice. For these reasons we have made no reference to the very large series of results given by Bain (1948) for hospitals in the United States of America.

At the end of approximately one month, 50 per cent. of the infants in the present survey were breast-fed without supplementary diet; four other available estimates are shown in Table VIII, and in each case the corresponding proportion was 70 per cent. or over. At the same age, 65 per cent. of the Belfast infants in the present survey were receiving breast milk with or without supplements, and this proportion was exceeded by all but one of the other eight available estimates. The exception was the estimate of 63 per cent. made by Douglas (1950), which was based on the infants, surviving to their second year, whose mothers had been the subject of detailed study for National Survey of one week's births in England and Wales in 1946 (Royal College of Obstetricians and Gynaecologists, 1948). This series represents one of the few surveys based on a random sample of maternities, and although the breast-feeding data was obtained retrospectively and excludes those infants who died in their first year, it is probably among the most reliable of recent estimates.

At approximately the end of the third month, only 23 per cent. of the infants in the present series were breast-fed without supplements. Estimates

TABLE VIII

PERCENTAGE DISTRIBUTION OF INFANTS BY METHOD OF FEEDING AT VARIOUS APPROXIMATE AGES
(Belfast results compared with other published results)

Reference		Survey		Approximate age (mths)						Remarks
				One		Three		Six		
Author	Date	Place	Date	B	B & B +	B	B & B +	B	B & B +	
Present survey	1954	Belfast	1951–52	50	65	23	37	6	19	500 infants followed from birth out of 558
Deeny and Murdock	1944	Belfast	1941–42		75		61		43	Retrospective data on 477 infants available at one year out of 671 randomly selected
Douglas	1950	Gt. Britain	1946		63		44		31	4,669 infants followed from birth
Crosse and Waller	1943	Birmingham	1938–42				53			M.O.H. returns of approximately 17,000 infants
Dummer	1949	Hitchin	1946–47	70	75	50	53	13	31	M.O.H. returns of 545 infants
Gordon	1942	Ilford	1938	73				44		M.O.H. returns
Hughes	1942	Newbiggen	1940			32	42	19	28	M.O.H. returns of 112 infants out of 117 attending clinic
Robinson	1939	Liverpool	1918–38			50		35		Retrospective data from clinic notes
Stewart and Westropp	1953	Oxford		75		61				574 infants followed from birth—volunteers in child survey
Stocks and Stang	1953	Area in Lancs.	1950			20		14		650 infants followed from birth out of 788
Wigley	1946	Barking	1943			61				1,182 infants
Blessing	1937	Evanston				19	44	7	17	437 private patients, majority hospital births
Kimball	1951	N.W. U.S.A.				37	46	20	23	409 private patients
Norval	1947	Rochester, Minn.			70		40		21	462 private patients, mothers anxious to breast-feed
Gemsjäger	1951–52	Hamburg	1949				62		33	M.O.H. returns
Hofmeier and Noack	1942	Germany				35	73	9	30	1,000 consecutive clinic patients
Kollman	1940	Nurnberg	1937		74		16			M.O.H. returns of 1,234 infants
Krug	1941	Cities of Germany	1937		88	58	58		25	M.O.H. returns
Pohlen	1939	Germany	1936		95		75		29	M.O.H. returns for the whole country
Ungar	1949	Germany	1940–42	83	95	39	80	5	40	858 infants attending clinic out of 884
Baumann	1947	St. Gall, Switzerland					65		17	M.O.H. returns
Merz	1946	Switzerland					55			Infant welfare records for whole country
Rudberg	1939	Stockholm	1922–37			66	79	30	59	Retrospective data from 2,013 mothers attending hospital out-patient department

from other sources vary between 19 and 66 per cent., and only two of the eleven available were lower than the present estimate. At the same age 37 per cent. of the Belfast infants in the present survey were receiving breast milk, with or without supplements. The seventeen other estimates in Table VIII range from 16 to 80 per cent., and only one is lower than that obtained from the present data. It is of interest to note, however, that several estimates (44 per cent., Douglas, 1950; 42 per cent., Hughes, 1942, from English sources; 44 per cent., Blessing, 1937; 46 per cent., Kimball, 1951; 40 per cent., Norval, 1947, from American sources) do not exceed the Belfast estimates by very much.

At the end of approximately 6 months only 6 per cent. of the present series of infants were fed on breast milk alone. Estimates from the other available sources ranged from 5 to 44 per cent., and again only one estimate of the available ten was lower than the present Belfast estimate. At the same age 19 per cent. of the present series were receiving breast milk with or without supplements. The fourteen other estimates range from 17 to 43 per cent. and only two were lower than that obtained in the present series.

If the estimates of Table VIII can be taken at their face value, then it appears that the proportion of breast-fed children, with or without supplements, in Belfast during the first 6 months of life is consistently low compared with results obtained elsewhere. But it must be emphasized again that the comparison is very crude, because of the lack of uniformity between investigations, and because no account can be taken of expected sampling variations, or basic differences in the types of births considered. Moreover, it should be noted that several of the investigations refer to data collected during the war years which would tend to increase the proportions breast-fed if the findings of Baumann (1947) are of general application.

SUMMARY

(1) Children born in the Royal Maternity Hospital Belfast, during September, October, and November, 1951, who survived their first 6 months of life and whose mothers, during this time, were Belfast residents were observed for 6 months or until breast feeding stopped. All children were included except multiple births, seven whose mothers refused to co-operate, and one whose mother died. A random sample of other Belfast births in the same 3 months was similarly observed, and again multiple births were excluded together with one whose mother would not co-operate.

(2) Observation was achieved by monthly visits to the children's homes by health visitors at which particulars of the feeding of the children were ascertained.

(3) After allowing for the possible effects of age of mother, parity, type of ante-natal care, and place of confinement, no significant difference was found at any age up to 6 months between the proportion of children breast-fed with or without supplements in the group born in the Royal Maternity Hospital Belfast, and in those born elsewhere.

(4) Pooling the data of the two groups leads to a reasonable estimate of the incidence of breast feeding in Belfast (Table VII).

(5) Comparison with work done elsewhere gives the impression that breast feeding with or without supplements is less common at all ages up to 6 months than has been generally reported from other areas. Lack of uniformity in such surveys is such that not too much credence should be given to this comparison.

Our thanks are due to the Staff of the Royal Maternity Hospital, Belfast, for their co-operation in allowing us to draw upon their patients, and to Dr. H. A. Warnock and the Health Visitors of the Maternity and Child Welfare Department of Belfast Corporation, without whose wholehearted support this investigation could not have been carried out. We are also indebted to Mr. J. D. Merrett and Miss D. B. I. Wood of the Department of Social and Preventive Medicine, Queen's University of Belfast, for considerable help with the analysis of the data and preparation of the manuscript.

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OXFORD CHILD HEALTH SURVEY*

STATURE AND SKELETAL MATURATION IN THE PRE-SCHOOL CHILD

BY

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In the majority of children the two complementary processes of growth† and skeletal maturation† are so well balanced that they tend to be thought of as two aspects of a single process. This view is partly justified by the fact that the two processes start together and must stop together, since there can be no further increase in height once the epiphyses of the long bones have closed. Yet growth and maturation can proceed quite independently, as is shown on the one hand by the dwarf (whose skeleton matures while growing very little) and on the other hand by the giant (whose stature is excessive for his maturity). Between these two pathological extremes it is natural to look for a range of physiological variation in the balance of rate of growth against rate of maturation. The child who comes to maturity quickly has had less time for growing, and, if he has only gained height at the average number of inches per year, must be a smaller adult. But it has often been observed that children who mature rapidly tend also to grow more rapidly than others. The question therefore arises, whether the more rapid growth of such children is sufficient to compensate for the shorter growth period at their disposal, or whether these physiologically fast maturers tend, as a group, to be small adults. Bayley (1943a and b, 1946), and Bayley and Pinneau (1952), in a study of pubescent children, concluded that rapidly maturing children tend to be shorter in the end than those who mature slowly.

The present study has two purposes:

(*a*) to discover whether observations on pre-school children provide any parallel to Bayley's findings;

(*b*) to see how the normal balance between growth and maturation is affected by an adverse environment.

MATERIAL

The observations on which this study is based were all made at the 6-monthly examinations of healthy children which formed a part of the Oxford Child Health Survey. The conduct of this survey has been described in detail by Thwaites (1950) and by Stewart and Russell (1952). Of the many items of information recorded at these examinations, five are relevant to the present study of growth and maturation:

(*i*) *Calendar Age.*—The numbers of children of each age for whom complete data were available are shown in Table I.

TABLE I

NUMBERS OF CHILDREN FOR WHOM BOTH STANDING HEIGHT AND TODD STANDARD WERE AVAILABLE

Age (years)	Social Class					
	Boys			Girls		
	I and II	IV and V	All Classes	I and II	IV and V	All Classes
1½	17	17	134	12	24	129
2	36	37	254	46	43	260
2½	42	35	238	40	43	257
3	35	36	242	42	43	261
3½	33	33	239	41	40	245
4	34	35	243	41	37	250
4½	31	32	225	40	42	238
5	31	36	233	38	41	234

(*ii*) *Sex.*—It is necessary to consider the sexes separately, since girls mature much more rapidly than boys.

(*iii*) *Standing Height.*—This was taken with the child in bare feet. Since very few of the year-old babies could co-operate sufficiently for this measurement to be taken, the youngest age group represented in this study is that of 18 months.

(*iv*) *Skeletal Maturity Status.*—This was assessed by the method of Todd (1937). Some unsatisfactory features of this method and of the concept of "skeletal age" ("stage" *passim*) have been discussed elsewhere

* This Survey has been financed by grants from the Nuffield Provincial Hospitals Trust and the Medical Research Council.

† In this paper "growth" means increase in stature. The term "skeletal maturation" has been well defined by Krogman (1949): "Maturity is an end product, an achieved state, and *maturation* a series of way stations along the path towards this final condition. There can be no reasonable doubt about the inevitability of morphological maturity; all things being normal there must come a time when the process of growth reaches a terminus, a time when adult or mature values are reached."

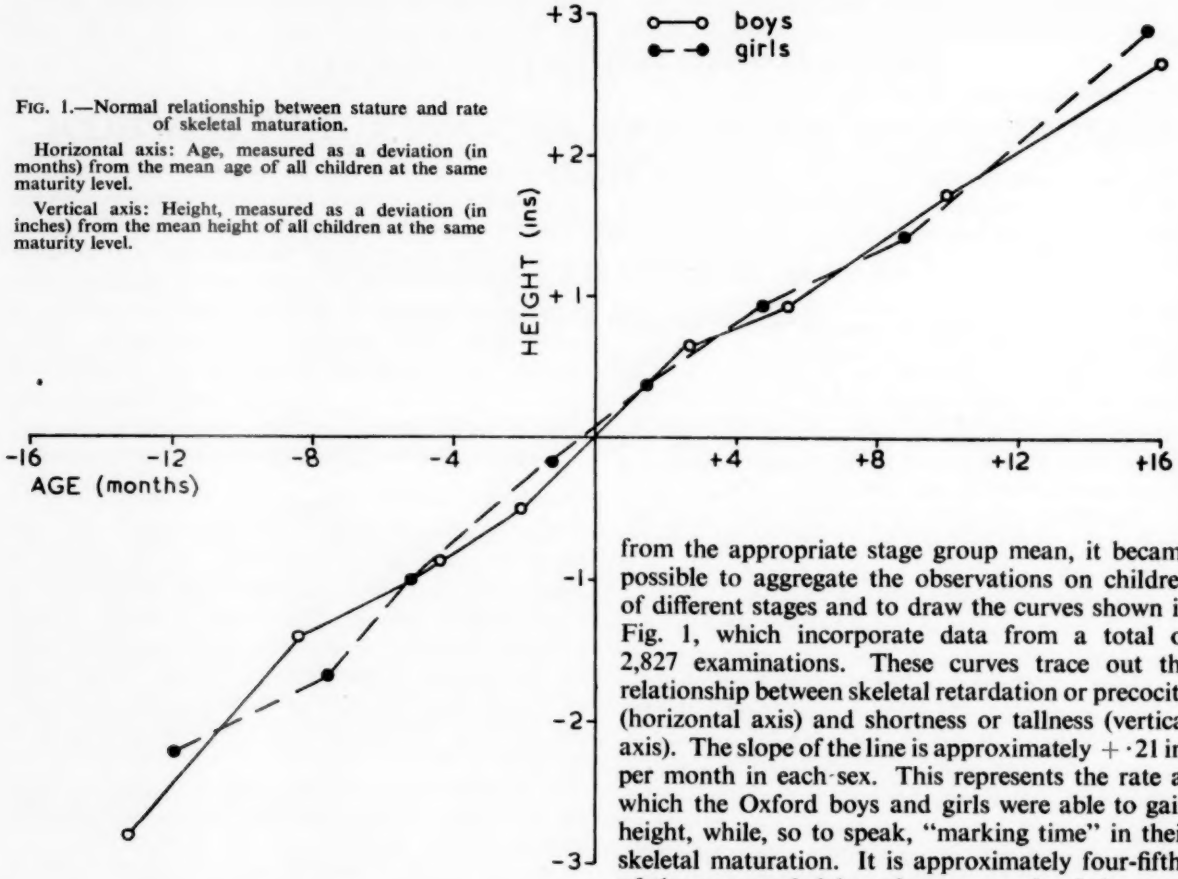

FIG. 1.—Normal relationship between stature and rate of skeletal maturation.

Horizontal axis: Age, measured as a deviation (in months) from the mean age of all children at the same maturity level.

Vertical axis: Height, measured as a deviation (in inches) from the mean height of all children at the same maturity level.

(Acheson, 1954). Nevertheless it has been used in this paper for the sake of comparability with the American growth studies (Shuttleworth, 1937, 1938; Bayley, 1943 a and b, 1946; Bayley and Pinneau, 1952).

(*v*) *Father's Occupation.*—This is the basis of the conventional classification by social-economic status into five Social Classes (Registrar-General, 1951).

PHYSIOLOGICAL RELATIONSHIP BETWEEN SKELETAL GROWTH AND MATURATION

It is convenient to group the observations by stage rather than by calendar age, and then to compare the heights of the children who have reached a stage early (*i.e.* the relatively young ones) with those who have reached it late. When this comparison was made from the Oxford data it was found that the slow maturers were taller than the average for equally mature children, while the fast maturers were shorter. This held good for both sexes and for all the stage-groups adequately covered by the material (*i.e.* Todd's standards 5 to 10 for boys and 5 to 11 for girls). When all the ages and measurements had been expressed in terms of deviations from the appropriate stage group mean, it became possible to aggregate the observations on children of different stages and to draw the curves shown in Fig. 1, which incorporate data from a total of 2,827 examinations. These curves trace out the relationship between skeletal retardation or precocity (horizontal axis) and shortness or tallness (vertical axis). The slope of the line is approximately $+\cdot21$ in. per month in each sex. This represents the rate at which the Oxford boys and girls were able to gain height, while, so to speak, "marking time" in their skeletal maturation. It is approximately four-fifths of the average height gain per month of the same group of children over the age range 18 months to 5 years. Thus these children do show a wide physiological variation in the balance between rate of growth and rate of maturation.

It must be conceded that the radiographs assigned to each stage group do not show skeletons of identical maturity. As the assessments are all made to the nearest Todd standard, there is a range of maturity within each stage group roughly equivalent to the amount of maturation taking place in 6 months of healthy development. It follows that an imaginary "average" child would not always appear exactly at the intersection of the axes in Fig. 1. He would repeatedly move up a diagonal line from a point about (-3 months, $-0\cdot7$ in.), on entering a stage group, to a point about ($+3$ months, $+0\cdot7$ in.) on leaving it. Thus any diagonal scatter of points within the ranges ±3 months and $\pm0\cdot7$ in. might be regarded as an artefact rather than as evidence of a real relationship between rate of maturation and height. But it will be seen that the points in Fig. 1 extend far outside these ranges, indicating real height contrasts between children with different

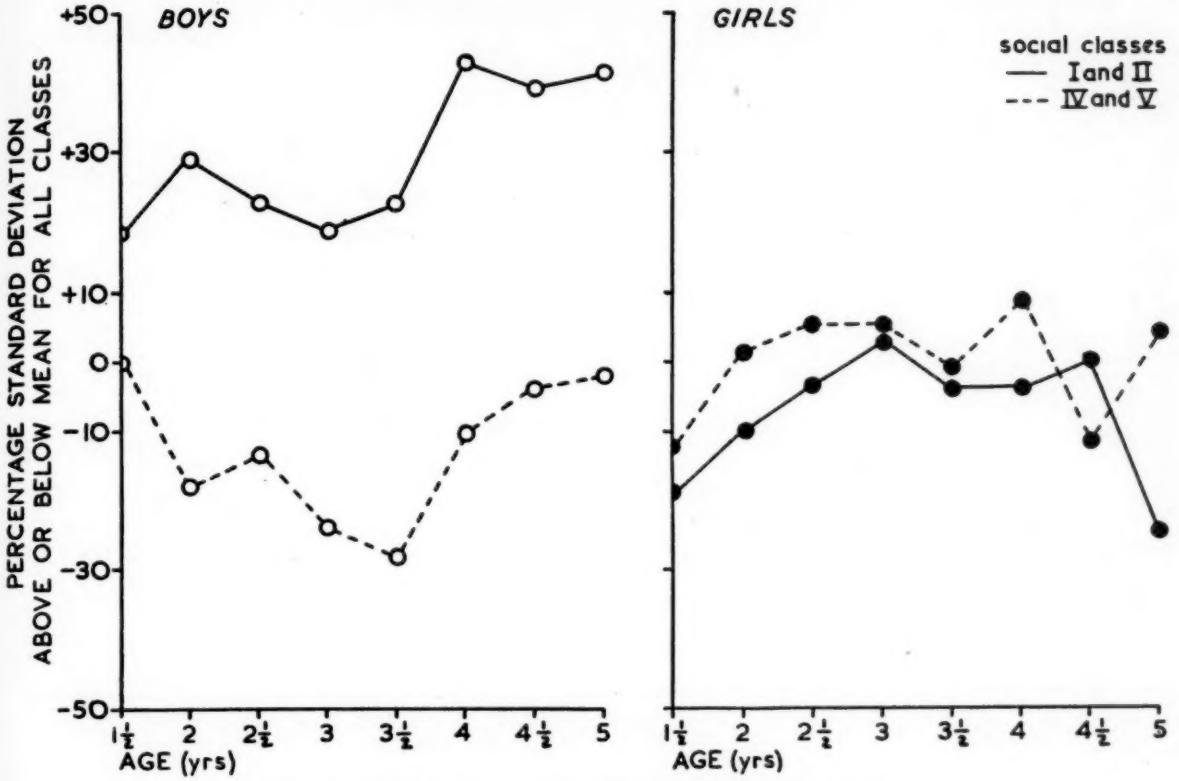

FIG. 2.—Comparative skeletal maturity of Social Classes I and II, and IV and V.

rates of maturation, as well as some artificial contrasts due to the approximate method of determining maturity status.*

There is no reason to doubt that children whose skeletons mature rapidly in the first few years of life tend also to mature rapidly in later childhood and in adolescence. Thus the present findings, together with those reported by Bayley (1943 a and b, 1946) imply that there is a group of children whose rapid maturation marks them out, well before they reach school age, as small adults of the future.

EFFECT OF ENVIRONMENT ON THE RELATION BETWEEN GROWTH AND MATURATION

It is well known that an unfavourable environment affects the growth of young children, and it has also been reported that bad environment can slow down the process of maturation (Stettner, 1920, 1921, 1931; De Wijn, 1953; Greulich, 1951; Greulich and others, 1953).

The question arises whether children whose maturation is held back in this way follow the same developmental pattern as the physiologically slow maturers, *i.e.* whether they tend to become rather tall adults. This question cannot, of course, be answered without considering the effect of the same environment on the rate of growth.

Figs 2 and 3 are intended to throw some light on these points. These Figures were constructed as follows. First the means and standard deviations of height and of stage were calculated for each sex for eight age groups. Then separate means were obtained for a group of well-to-do children (fathers in Social Class I or II) and for a group of poor children (fathers in Social Class IV or V). These latter means were then expressed as percentages of a standard deviation above or below the mean for all classes, and were plotted against age in Fig. 2 (maturation) and Fig. 3 (growth). The information in these Figures can be roughly summarized by averaging the social class deviations over all eight age-groups, as shown in Table II.

TABLE II

MEAN PERCENTAGE LEAD OF WELL-TO-DO OVER POORER CHILDREN OBSERVED FROM 1½ TO 5 YEARS AS A PERCENTAGE OF THE STANDARD DEVIATION FOR ALL CLASSES

Sex	Height	Maturity
Boys	+60	+43
Girls	+36	− 7

* A more precise method of determining maturity status (Acheson, 1954) was applied to a sub-sample of one hundred of the survey children, and led to curves very like those in Fig. 1.

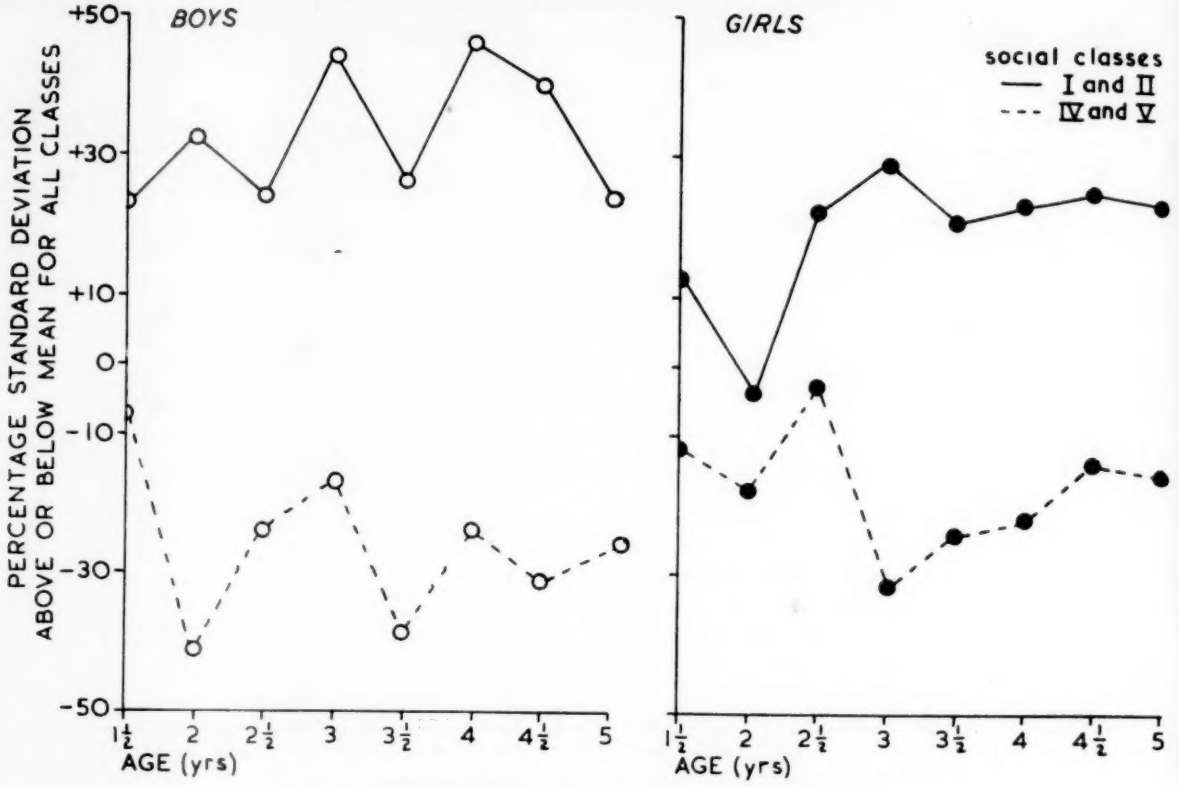

FIG. 3.—Comparative height of Social Classes I and II, and IV and V.

Fig. 2 shows that the Oxford boys in the poorest social groups were maturing more slowly than those in the best environment. The Oxford girls, on the other hand, did not show any regular social class difference in maturation. Thus the maturation of these girls, besides being more rapid than that of the boys, appeared to be less affected by environment. This tallies with the observations of Greulich (1951) and Greulich and others (1953) on child survivors of starvation and atomic bombing.

Fig. 3 shows that the group of boys in which slow maturation might be attributed to environment suffered a more than proportionate slowing down of growth. Thus they differed from the physiologically slow maturers by showing signs of a relatively short final height. The girls, whose rate of maturation did *not* appear to have been affected by environment, also showed a clear social differentiation in height. It follows that, if stage groups are substituted for age groups as the basis of comparison, these girls must show greater social differentiation in stature than the boys. This is illustrated in Fig. 4, in which the height advantage of the well-to-do over the poorer boys of equal maturity is barely perceptible, while the well-to-do girls show a lead of more than half an inch. If these tendencies persisted throughout the later stages of childhood, one would expect to find that social class differences in final height, in so far as they are determined by environment, would be greater in girls than in boys.

Although social class has been interpreted in this section as an index of environment, it should be borne in mind that some social class differences may themselves be genetic in origin. Between the fathers of Social Classes I and II and those of Social Classes IV and V there was a height difference of 1·7 in. in favour of the well-to-do, while the more prosperous mothers were 1·6 in. taller. But it is not practicable to push the analysis any further, since differences between the parents (many of whom grew up in circumstances very like those of their adult lives) must in turn owe something to environment.

DISCUSSION

The literature on child development contains many reports on rates of growth (*i.e.* increase in stature per unit increase in calendar age). These rates have been reported separately for the sexes, for economic groups, and for well and ill children. Such reports have thrown much light on the intermediate years of development, but they provide no satisfactory

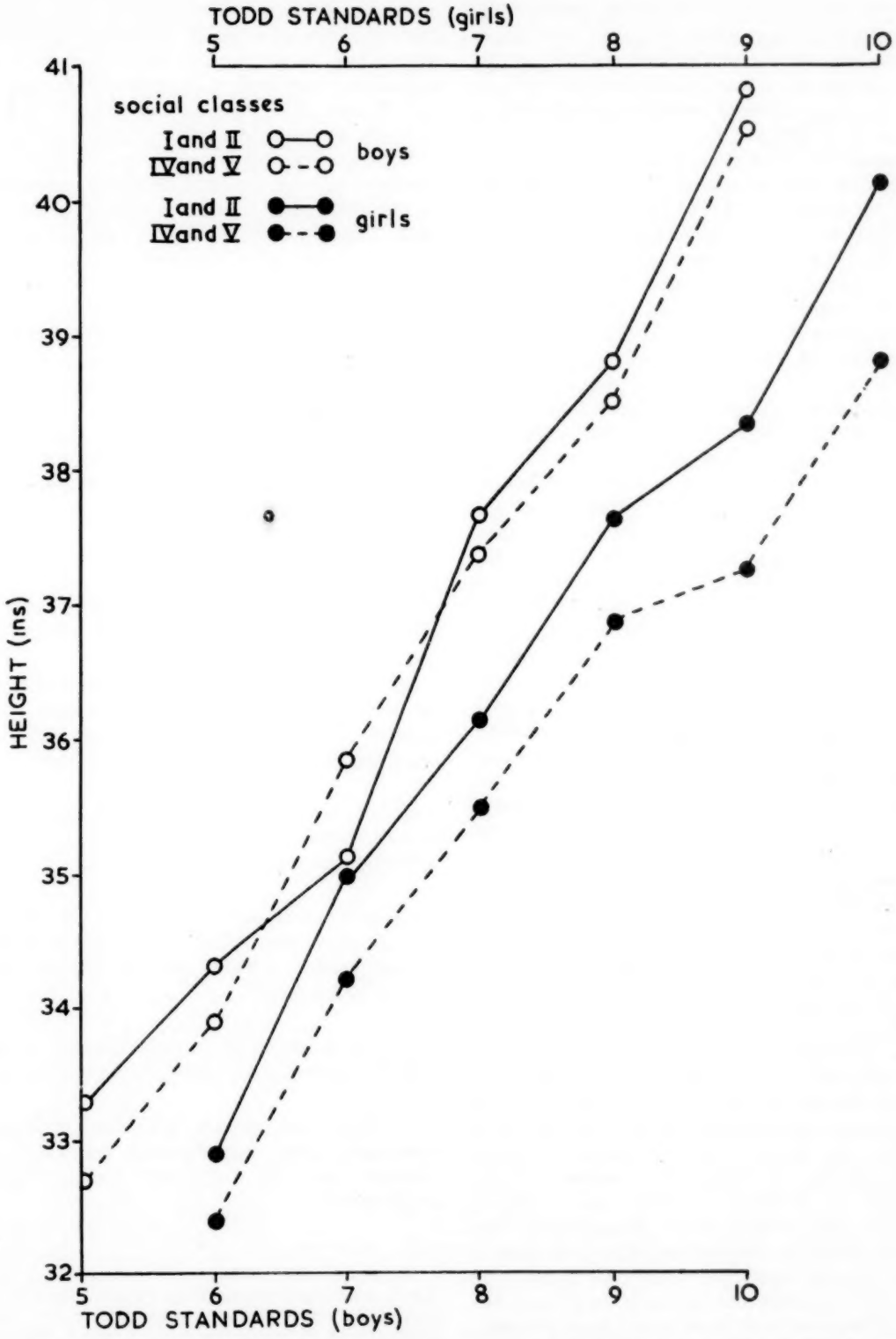

FIG. 4.—Heights of boys and girls in different social groups. Comparisons based on children of equal skeletal maturity.

evidence on one topic of considerable interest: the determination of final adult height. The final height of the mature individual depends on his rate of growth *relative* to his rate of maturation, summed over all the stages of maturation from conception to closure of the epiphyses.

It is reasonable to suppose that for children living under ideal conditions both the rate of growth and the rate of maturation would be determined completely by heredity. It is convenient to have a name for the ideal relationship between these rates, and we may therefore define the "growth potential" of a child as his increase in stature, under ideal conditions, per unit increase in maturity. If a child living in an imperfect environment suffered equivalent reductions in rate of growth and in rate of maturation, he would still succeed in fulfilling his "growth potential" and his adult height would not be affected. But the Oxford data suggest that imperfections in the environment do *not* have an equivalent effect on these two rates, and that it is by means of this inequality that environment can exercise an effect on adult height. If, as appears to be the case, the growth rate is the more affected the child will fail to fulfil his full "growth potential", and thus tend to become a smaller adult. In these terms the extra height of adults belonging to the richer groups of the community would be said to have two components: first a rather larger hereditary "growth potential" and second, a greater success (attributable to environment) in fulfilling the "growth potential" available to them.

It has been shown (Clements, 1953) that the children of to-day are taller, age for age, than the children of recent decades; there can be no question of attributing this change to a spontaneous increase in the "growth potential" of the community, in fact the difference must be due to improvements in nutrition, housing, clothing, and health. It has also been shown (Howe and Schiller, 1952) that the height of German schoolchildren fluctuated with their country's fortunes during the past 40 years, and that although the general trend was upwards, it was disturbed by such events as the slump of 1930 and the two world wars. However, it is not certain whether environmental improvements merely accelerate the process of development towards physical maturity, or whether they enable a greater proportion of children to fulfil their "growth potential". The present set of observations, since they were made on children less than one-third of the way towards maturity, cannot do more than suggest which of these alternatives is the correct one. But, taken together with the other available evidence, they do lend some support to the hypothesis of increasing fulfilment of "growth potential", and thus of a net increase in the adult height of the population. It is a further point in favour of this suggestion that both Clements (1953) and Howe and Schiller (1952) report the greatest fluctuation in height in the poorest section of the community.

The apparent difference between the sexes in their response to environmental conditions may prove to be one of the most significant features of the Oxford data. That girls are less liable to retarded maturation than boys has been reported by Greulich (1951) and Greulich and others (1953).

The present observations suggest an interesting paradox: that the sex which brooks the least delay in its progress towards maturity may also be the sex which in adult life bears the clearest marks of poor childhood environment.

The fact that the average height of men is above that for women may be regarded as a special case of the association between slow maturation and above average stature in adult life.

Summary

(1) From clinical and radiological observations on 580 pre-school children at Oxford it is found that:

(*a*) when all social groups are considered together for any skeletal maturity status, slowly maturing children are taller than the mean, and rapidly maturing children shorter than the mean;

(*b*) age for age, children of both sexes from the poorer social groups are smaller than children of well-to-do parents;

(*c*) the slow maturation found in the poorer boys is not associated with the greater-than-average height, which is a feature of slow maturation in the survey as a whole;

(*d*) the maturation of girls appears to be less affected by social environment than that of the boys.

(2) These findings are discussed in terms of a genetically determined "growth potential", which depends for its fulfilment on a favourable environment.

We wish to acknowledge our indebtedness to Dr. F. H. Kemp, who was responsible for planning the radiological part of the survey and who assessed the many thousands of hand films on which this study is based. We also wish to thank Dr. Alice Stewart for advice and criticism.

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INFLUENCE OF THE PRE-NATAL ENVIRONMENT ON POST-NATAL GROWTH

BY

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The pre-natal environment may modify the state of development of the child at birth by influencing the rate or duration of pre-natal growth. Size of litter, for example, has a substantial effect on both, for in multiple pregnancy foetal growth is retarded during the last weeks of gestation, and onset of labour is earlier than in single pregnancy (McKeown and Record, 1952). Parity also influences the rate of foetal growth, which is greater in later born than in first born (McKeown and Record, 1953), but it has only a small effect on duration of gestation (Karn and Penrose, 1951). Maternal age has little influence on rate of growth, and none on duration of gestation when a correction is introduced for length of cycle (Gibson and Dougray, 1953).

These environmental influences are modified after birth. They may be removed, as in the case of the gross pre-natal handicaps associated with multiple pregnancy, or turned in another direction, as in the case of the differences related to birth order (the pre-natal environment favours later born; the post-natal environment favours first born). Post-natal growth therefore reflects both:

(*a*) the influence of the pre-natal environment on the state of development at birth,
(*b*) the changes in environment which appear after birth.

We here examine the influence of duration of gestation, birth rank and maternal age on post-natal development, using as indices of development the weight and length of the child. Data were recorded in respect of all children (1,327) born between April 1, 1949, and March 31, 1950, whose mothers were domiciled in the County Borough of Smethwick. The weight and length of each child were measured at birth, and at 3, 6, 9, 12, and 24 months after birth. The analysis which follows is based on 334 boys and 307 girls for whom data were complete, and whose post-natal measurements were all recorded within 3 weeks of each quarter.

Total correlations of infant weight and height with:

(*a*) duration of gestation,
(*b*) birth rank,
(*c*) maternal age

are given in the Appendix. Partial correlations are also given in each case after correcting for the effects of the other two variables and the heights of both parents.

Duration of Gestation

It is of course well known that birth weight increases with duration of gestation, correlation between the two variables being about 0·4 (Karn and Penrose, 1951).

It has been shown by Lowe and Gibson (1953) that the correlation between infant weight and gestation changes after birth, and that at the third birthday there was no obvious association between the two variables. Indeed there was a small negative correlation when a correction was introduced for birth weight and birth rank.

The data given separately for boys and girls in the Appendix confirm and extend these observations. At birth there are substantial correlations between infant weight and length and duration of gestation; the correlations decrease after birth. Figs 1 and 2 (opposite) respectively show partial correlations, holding constant parental height, birth rank, and maternal age, between:

(*a*) infant weight and duration of gestation,
(*b*) infant length and duration of gestation.

The marked association between these variables at birth changes rapidly after birth, and the influence of gestation on weight and length is trivial by the end of the second year.

This result suggests that for births delivered within a few weeks of term, length of time spent in the uterus has little bearing on subsequent development (of which weight and length are fairly reliable indices). Indeed, since individuals delivered after short gestation are smaller than average at birth, the fact that they are very nearly of average size at 2 years after birth suggests that for a time at least they grow more rapidly than individuals delivered after long gestation.

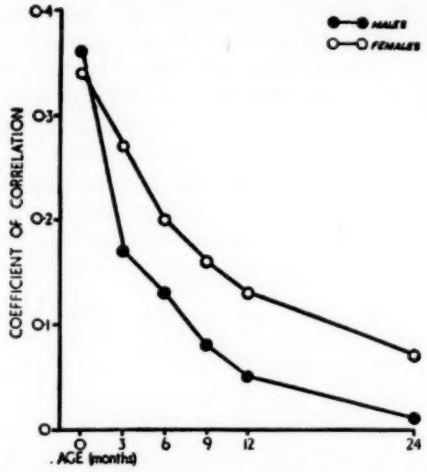

FIG. 1.—Correlation between infant weight and duration of gestation, corrected for parental height, birth rank, and maternal age.

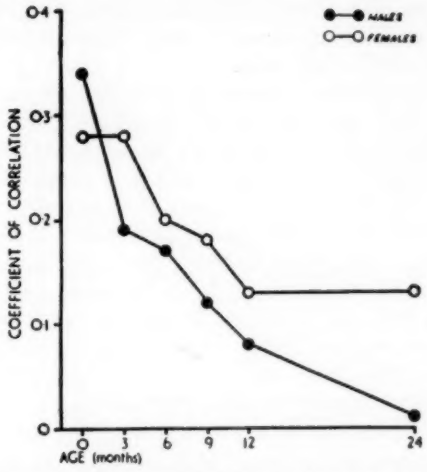

FIG. 2.—Correlation between infant length and duration of gestation, corrected for parental height, birth rank, and maternal age.

BIRTH RANK

It is now well established that birth weight increases with birth rank. This association is not due to variation in duration of gestation (indeed there is a slight negative correlation between gestation and birth rank), and must therefore be attributed to an increase in rate of foetal growth with birth order. It has recently been shown (McKeown and Record, 1953) that a difference in rate of growth between first and later born appears at about 36–37 weeks gestation; it may be explained largely, though not entirely, by the observation that placentae of later born are larger than those of first born.

The influence of birth rank on post-natal growth was previously examined by Paton and Findlay (1926). They noted that the positive correlation between weight and birth rank fell after birth, and that by the end of the first year there was a substantial negative correlation.

Our own data (see Appendix) are consistent with this report. Figs 3 and 4 respectively give partial correlations, holding constant parental height, gestation, and maternal age, between:

(*a*) weight and birth rank,
(*b*) length and birth rank.

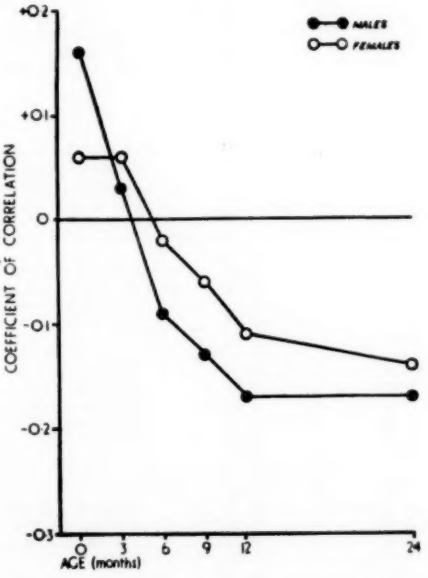

FIG. 3.—Correlation between infant weight and birth rank, corrected for parental height, maternal age, and duration of gestation.

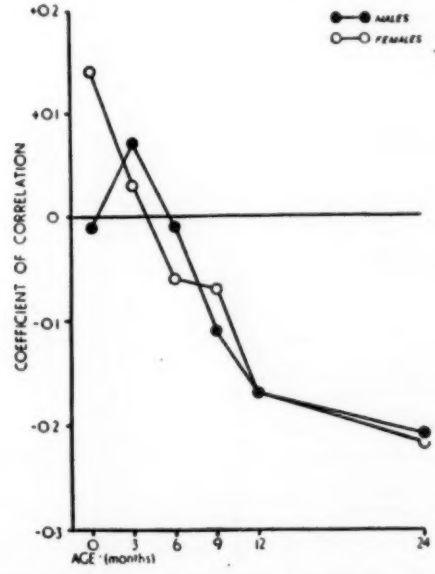

FIG. 4.—Correlation between infant length and birth rank, corrected for parental height, maternal age, and duration of gestation.

The positive correlations established at birth are rapidly eliminated, and at 2 years there are negative correlations in each case.

The association between birth rank and pre-natal growth has been discussed elsewhere (McKeown and Record, 1953). The most plausible explanation of the negative correlation which is rapidly established after birth is the association between social and economic circumstances and place in family. In general, first born children are more favourably placed than later born, both because well-to-do parents tend to have small families, and because poor parents are better off at birth of their first children. The post-natal handicaps experienced by later born children are also reflected in an increase in infant mortality with increasing birth rank (Gibson and McKeown, 1952).

A comparison between first and later born in a population of births is limited in so far as it does not permit us to express an opinion about the influence of birth rank on growth within the same family. (It seems evident that this influence must vary according to the matter under examination, and the social and economic circumstances of the family.) This problem was considered by Bowles (1932) and Howells (1948), who compared the stature of younger children with that of older sibs. In both cases the comparisons were made in adult life, and they are somewhat inconclusive because no allowance was made for the fact that at the time of examination later born were younger than first born, and might not have completed their growth.

Maternal Age

Of the three variables here considered in relation to growth, maternal age is perhaps the least interesting. As already noted, it has virtually no influence on birth weight. But the post-natal environment is related to age, for the reason that in general well-to-do mothers have their children at a somewhat later age than poor mothers.

Correlations between:

(*a*) weight and age,

(*b*) length and age (see Appendix, below)

are somewhat irregular, but they appear to increase slightly after birth, and to be positive at 2 years.

Appendix

Correlated Variables	Age (mths)	Coefficient of Total Correlation		Coefficient of Partial Correlation		Variables held Constant in Computing Partial Correlation
		Males	Females	Males	Females	
Weight of infant and duration of gestation	0	0·37	0·36	0·36	0·34	Heights of father and mother, birth rank, and age of mother
	3	0·19	0·29	0·17	0·27	
	6	0·15	0·21	0·13	0·20	
	9	0·09	0·18	0·08	0·16	
	12	0·06	0·15	0·05	0·13	
	24	0·03	0·11	0·01	0·09	
Length of infant and duration of gestation	0	0·35	0·30	0·34	0·28	Heights of father and mother, birth rank, and age of mother
	3	0·22	0·31	0·19	0·28	
	6	0·19	0·22	0·17	0·20	
	9	0·14	0·21	0·12	0·18	
	12	0·10	0·16	0·08	0·13	
	24	0·03	0·16	0·01	0·13	
Weight of infant and birth rank	0	0·17	0·07	0·16	0·06	Heights of father and mother, duration of gestation, and age of mother
	3	0·08	0·05	0·03	0·06	
	6	−0·03	−0·01	−0·09	−0·02	
	9	−0·09	−0·08	−0·13	−0·06	
	12	−0·14	−0·11	−0·17	−0·11	
	24	−0·14	−0·12	−0·17	−0·14	
Length of infant and birth rank	0	0·06	0·10	−0·01	0·14	Heights of father and mother, duration of gestation, and age of mother
	3	0·13	0·02	0·07	0·03	
	6	0·06	−0·06	−0·01	−0·06	
	9	−0·08	−0·09	−0·11	−0·07	
	12	−0·11	−0·23	−0·17	−0·17	
	24	−0·17	−0·24	−0·21	−0·22	
Weight of infant and age of mother	0	0·08	0·05	−0·06	0·03	Heights of father and mother, duration of gestation, and birth rank
	3	0·10	0·00	0·03	−0·01	
	6	0·09	0·00	0·10	0·02	
	9	0·04	−0·07	0·08	−0·02	
	12	0·01	−0·04	0·08	0·04	
	24	0·00	−0·02	0·07	0·07	
Length of infant and age of mother	0	0·11	0·00	0·07	−0·05	Heights of father and mother, duration of gestation, and birth rank.
	3	0·14	0·00	0·05	0·01	
	6	0·13	−0·01	0·08	0·05	
	9	0·02	−0·04	0·04	0·02	
	12	0·07	−0·15	0·12	−0·02	
	24	0·02	−0·12	0·10	0·03	
Standard Error		0·06	0·06	0·06	0·06	

SUMMARY

(1) The association of rate of post-natal growth (as indicated by weight and length) at birth, and at 3, 6, 9, 12, and 24 months after birth with duration of gestation, birth rank, and maternal age is examined in 334 boys and 307 girls.

(2) Positive correlations at birth between weight and duration of gestation, and between length and duration of gestation, decrease after birth, and by the end of the second year the influence of gestation period is trivial.

(3) Positive correlations at birth between weight and birth rank, and between length and birth rank, are rapidly eliminated after birth, and at 2 years there are negative correlations in each case.

(4) At birth maternal age has virtually no influence on weight and length. Correlations between these variables after birth are somewhat irregular, but appear to increase slightly and to be positive at 2 years.

We are indebted to Miss Ida Giles, Miss Eileen Gibson, Mrs. Laurie Leaver, and Mrs. Barbara Lowe, who recorded most of the observations at home and in clinics. The research was assisted by a grant from the Birmingham Students' Social Services Fund.

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SURVEY OF ENTRANTS TO NURSE TRAINING SCHOOLS AND OF STUDENT-NURSE WASTAGE IN THE BIRMINGHAM REGION

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1. Introduction

One of the most urgent problems confronting the National Health Service is that of providing sufficient nursing staff. It will be possible to maintain the hospitals at the existing level of efficiency only if it is possible to provide enough adequately trained nurses in future years. To a large extent the quality and quantity of the nursing staffs, as of the Health Service in general, must depend on how much the community can afford to spend.

Doubtless financial difficulties in Great Britain will restrict expenditure on the hospitals for several years to come, though annual salary increments with the rising cost of provisions, fuel, light, and water may involve greater expenditure. Meanwhile more lucrative opportunities in industry or government employment may adversely influence readiness to engage in nursing.

The hospitals cannot compete with industry or the civil service in so far as recruitment depends on remuneration offered; and the hours of duty required by a hospital are more exacting. Furthermore, we must not neglect population trends which affect not only the future pattern of hospitalized disease but also the potential reservoir of persons from which the nursing service draws its recruits. Current estimates show that in 1960 there will be almost half a million fewer females between the ages of 18 to 30 years inclusive, than in 1951.

For this reason alone we may expect that recruitment of women to the nursing services during the remaining years of this decade will present increasing difficulties.

2. Shortage of Nursing Staff in the Birmingham Region

What follows refers to nursing staff requirements in the Birmingham Hospital Region with special reference to:

(*i*) the number of beds not in use owing to nursing staff shortage;
(*ii*) the stated requirements of hospitals in terms of full-time staff equivalents.

It appears that 3,250 beds out of a total of 44,350 were not in use at the end of 1952, and lack of nursing staff accounted for almost 2,500 of these. Hence the overall bed availability could increase by 6 per cent if sufficient staff were available.

However, the number of unused beds is only a rough measure of the shortages, since staff requirements vary considerably by type of hospital, and beds do not necessarily go out of use when nurses are in short supply. Thus mental hospitals and mental deficiency institutions, where bed space is in great demand, though seriously short of staff, have relatively few beds not in use. This situation also exists at chronic sick hospitals and sanatoria, where shortage of nursing staff is also acute. On the other hand, the measure given by (*ii*) may well exaggerate a nursing staff shortage in so far as hospitals tend to fix their nursing establishments at an unduly optimistic level.

Hospitals in this Region employ 10,210 full-time and 2,850 part-time nurses, of whom 4,020 and 820 respectively are already trained. Their stated additional requirements are 4,100 full-time nurses (or full-time equivalents) of all grades, of whom 1,065 should be already trained. Out of this total the mental hospitals and mental deficiency institutions assess their requirements at 1,290 nurses, of whom 492 must be already trained. Without here attempting to assess more realistically the requirements of the hospital nursing services at the present time, it is probably true to say that all the trained staff available for employment are already in the Service, and that in certain types of hospital the present rate of recruitment and training of student nurses cannot even replace those due to retire during the remaining years of this decade. Meanwhile there is no prospect in the foreseeable future of any increase in the rate of recruitment. Hence it is of the utmost importance that those attracted to the hospital service shall remain in it. Only by recruitment and training of student nurses and by their retention in the hospital service shall we be able to safeguard the future.

Before undertaking this survey it was realized that student-nurse wastage varies with type of

training school, and that the extent of this variation is much more important than the range of variation among hospitals of the same type. Whereas the latter is largely due to local conditions the former reflects differences with respect to facilities available, to the character and scope of training, and presumably to type of entrant. An indication of the magnitude of these differences was obtained from the report of the Working Party on the Recruitment and Training of Nurses, which gives *inter alia* an analysis of the estimated intake and wastage of student nurses over the period 1937 to 1943. However, the pattern of nurse recruitment undoubtedly changed after the end of the war and a more up-to-date analysis was deemed to be essential.

3. Method of Collection and Source of Data

An exhaustive investigation of the problem of student-nurse wastage necessitates the collection of detailed information about the students entering training during a specified period, so that the progress of each student may be studied from the time of entering to that of leaving. With this end in view, two questionnaires were designed for use in the Birmingham Region; the one relating to the student and the other to the hospital providing the training. To allow a sufficient period for students to complete their training, the year chosen for the survey was 1946, and hospitals were asked to complete a questionnaire for every student entering training during that year.

Questionnaires were duly completed by all hospitals in the Birmingham Region with training schools. In what follows we consider what aspects of student-nurse wastage they elucidate, and the results of a detailed analysis of the type of person entering the schools during 1946 are also given. Not all information presumptively relevant to the inquiry was available on existing records, but the results obtained give clear indications of the relative importance of some circumstances which contribute to student wastage.

4. Age of Students at Entry

It will be recalled that under the *Nurses Rules, Approval Instrument, 1951*, the minimum age of entry for nurse training as from the first day of August, 1952, is 18 years. In view of the controversy which resulted from the application of this ruling and of its importance from our viewpoint here, we shall first consider age at entry. Table I shows, for each type of training, percentage age and sex distributions for students entering upon nurse training in 1946, the actual numbers involved being given at the foot of the columns.

As would be expected, the Table shows that for all types of training school male students started at a much later age than female students. This sex differential was accentuated in 1946 by the intake of male students in the older age groups from His Majesty's Forces. It is interesting to compare these results with those obtained from a survey of age of entry of student nurses to training in 1950 and 1951. If both sexes are considered together, the following proportions of students who entered the various types of training schools were under 18 years of age at entry:

Type of Training School	1946		1950		1951	
	No. of Entrants	Per cent. under 18	No. of Entrants	Per cent. under 18	No. of Entrants	Per cent. under 18
General	866	17·8	957	34·0	888	38·2
Mental	173	11·6	153	11·2	120	6·7
Mental Deficiency ..	68	12·0	59	10·2	33	6·1
Fever	26	30·7	70	64·3	42	61·9
Affiliated	158	46·8	212	61·8	172	56·4
All Types	1,291	20·8	1,451	36·2	1,255	37·6

Table I

AGE AT ENTRY TO NURSE TRAINING, BY SEX

Percentage Distributions by Type of Training School

Age Group (yrs.)	Type of Training School														Totals	
	General		Mental		Mental Deficiency		Fever		Tuberculosis		Orthopaedic		Ophthalmic			
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Under 17 ..	—	1·1	1·4	2·0	—	11·5	—	11·5	—	6·3	—	31·4	—	—	0·7	3·8
17– ..	—	17·2	2·7	15·2	7·1	23·1	—	19·2	—	9·5	—	47·2	—	50·0	3·4	19·1
18– ..	—	24·4	2·7	20·2	7·1	11·5	—	3·9	—	14·3	—	11·4	—	5·6	3·4	21·7
19– ..	—	13·9	2·7	9·1	—	3·9	—	23·1	—	17·5	—	2·9	—	11·1	1·4	12·9
20–24 ..	34·8	31·5	29·7	34·4	21·5	34·6	—	26·8	14·3	25·4	—	5·7	—	33·3	27·4	29·7
25–29 ..	21·7	6·8	41·8	12·1	26·2	3·9	—	7·7	71·4	15·9	—	1·4	—	—	35·6	7·3
30– ..	43·5	3·4	17·6	—	26·2	11·5	—	3·9	14·3	3·2	—	—	—	—	24·0	3·1
40 and over	—	—	1·4	1·0	2·4	—	—	—	—	1·6	—	—	—	—	1·4	0·2
Not Known	—	1·7	—	6·0	9·5	—	—	3·9	—	6·3	—	—	—	—	2·7	2·2
Totals ..	100·0 (23)	100·0 (843)	100·0 (74)	100·0 (99)	100·0 (42)	100·0 (26)	—	100·0 (26)	100·0 (7)	100·0 (63)	—	100·0 (70)	—	100·0 (18)	100·0 (146)	100·0 (1,145)

TABLE II

AGE AT ENTRY AND RESULT OF TRAINING

Age Group (yrs)	Type of Training School														Total	
	General		Mental		Mental Deficiency		Fever		Tuberculosis		Orthopaedic		Ophthalmic			
	Total Students	Per cent. Successful	Total Students	Per cent. Successful	Total Students	Per cent. Successful	Total Students	Per cent. Successful	Total Students	Per cent. Successful	Total Students	Per cent. Successful	Total Students	Per cent. Successful	Total Students	Per cent. Successful
Under 18 ..	154	39·0	20	10·0	12	8·3	8	37·5	8	25·0	55	49·1	9	22·2	266	36·5
18– ..	207	51·7	22	4·5	6	0·0	1	100·0	9	22·2	8	42·9	1	0·0	254	44·9
19– ..	117	46·2	11	0·0	1	0·0	6	33·3	12	58·3	2	0·0	2	100·0	151	43·0
20–24 ..	274	48·2	56	14·3	18	27·8	7	57·2	18	27·8	4	33·3	6	50·0	383	41·3
25–29 ..	63	50·8	43	32·6	12	16·7	2	100·0	15	33·3	1	0·0	—	—	136	40·4
30– ..	39	56·4	13	53·8	14	50·0	1	0·0	3	66·7	—	—	—	—	70	54·3
40 and over	—	—	2	0·0	1	0·0	—	—	1	0·0	—	—	—	—	4	0·0
Totals* ..	854	47·7	167	19·2	64	23·4	25	48·0	66	34·8	70	44·3	18	38·9	1,264	41·7

* These totals exclude students whose ages were unknown

Differences between the proportions exhibited for 1951 and 1946 are most spectacular in the case of both the general and the fever training schools, and it is of particular interest to examine the results of training for students in various age groups. The results of this analysis are given in Table II.

In general training schools the proportion successful is lowest in the first age group, *viz.*, under the age of 18. The figures for mental training schools are even more striking: of a total of 53 students entering under the age of 20 only three completed training, and in the case of mental deficiency training only one student out of nineteen who entered under the age of 20 was successful. In view of the small numbers involved, it is difficult to draw any firm conclusions as regards fever and ophthalmic training schools. If we consider all schools together, it would appear that the student entering training under the age of 18 is even more likely to fall out than the older student. The application of the minimum age bar would seem to be particularly relevant to mental hospitals and mental defective institutions.

5. EDUCATIONAL BACKGROUND

A second circumstance of particular relevance to the inquiry is the educational background of the student. As one criterion, the age of completion of full-time education was requested for each student (Table III). Unfortunately this information was not available in respect of 24 per cent. of all students entering training in 1946.

In training schools as a whole, a high proportion of students (36·2 per cent.) left school at the age of 14 and hence presumptively had only an elementary education and certainly no academic qualifications. This preponderance was particularly noticeable among students entering mental and mental deficiency training schools. A further 137 (10·5 per cent.) students were known to have left school at 15 and although some of these had attended secondary or grammar schools, only five had obtained school certificate or matriculated. Thus it may be said that almost half the students entering nursing in 1946 were known to have received only the minimum of education. Table III also shows that 17·7 per cent.

TABLE III

AGE AT COMPLETION OF FULL-TIME EDUCATION

Percentage Distributions by Type of Training School

Age (yrs)	Type of Training School							Total
	General	Mental	Mental Deficiency	Fever	Tuberculosis	Orthopaedic	Ophthalmic	
14	33·7	53·7	73·6	7·7	27·2	8·6	27·8	36·2
15	11·1	8·1	11·7	7·7	17·1	4·3	5·5	10·5
16	20·4	8·1	2·9	15·4	10·0	25·7	39·0	17·7
17	7·8	2·3	1·5	—	4·3	37·2	5·5	8·0
18	3·8	1·2	—	3·8	—	1·4	11·1	3·0
19	0·5	—	1·5	—	—	—	—	0·4
Over 19 ..	0·3	0·6	—	—	—	—	—	0·3
Not Known ..	22·4	26·0	8·8	65·4	41·4	22·8	11·1	23·9
Totals	100·0 (866)	100·0 (173)	100·0 (68)	100·0 (26)	100·0 (70)	100·0 (70)	100·0 (18)	100·0 (1,291)

of all students were known to have left school at age 16, 8 per cent. at 17, and only 3·7 per cent. at 18 or over. Most of those who left school at 16 were known to have had a secondary or grammar school education, but 54 per cent. held no certificate qualification.

It is difficult to draw conclusions with respect to individual training schools (except the general and mental training schools) because of the small numbers involved. However, to complete our picture with regard to the bearing of educational background on student wastage, an analysis of results of training by type of background is given in Table IV for all students irrespective of training school. This Table shows the numbers in the major educational groups and also the proportion successful in each class. Only students whose standard of education is known (*i.e.*, year of completion, type of school, and qualification attained) are included. It will be noticed that in every age category the proportion of successes is considerably higher among students possessing school certificate or matriculation than among those with no qualification; percentages based upon very small numbers are shown in brackets. The possession of such a qualification appears to be a more important factor than the time spent on education, since the proportion of successful students without qualification varies little with age of completion of full-time education. These results show that the best type of student from the educational viewpoint is the one who stayed at a secondary or grammar school until 16 or 17 years of age and obtained a school certificate.

6. Pre-Nursing Courses and Previous Experience

In 1946 very few pre-nursing courses appear to have been run by education authorities. Only nine students had attended such courses, and of these seven completed training. No conclusions regarding the value of such courses can therefore be made at this stage. However, an analysis of students who had nursing experience before starting to train proved to be far more rewarding. We may distinguish three groups:

(*i*) students who previously obtained a nursing qualification;

TABLE IV

RESULT OF TRAINING BY EDUCATIONAL BACKGROUND

Age at Completion of Full-Time Education (yrs)	Educational Grade		Total Students	Per cent. Successful
	Type of School	Qualification		
14	Elementary only	None	467	37·9
15	Elementary only	None	53	41·5
	Elementary and Secondary or Grammar	None	37	35·1
		School Certificate or Matriculation	5	(60·0)
	Elementary and Technical or Commercial College	None	16	50·0
	Other	None	10	40·0
	All Schools	None	116	40·5
		School Certificate or Matriculation	5	(60·0)
16	Elementary and Secondary or Grammar	None	67	47·8
		School Certificate or Matriculation	62	69·3
	Secondary or Grammar only	None	18	61·1
		School Certificate or Matriculation	11	63·6
	Elementary and Technical or Commercial College	None	18	33·3
		School Certificate or Matriculation	2	(50·0)
	Other	None	16	37·5
	All Schools	None	119	46·2
		School Certificate or Matriculation	75	68·0
17	Elementary and Secondary or Grammar	None	16	50·0
		School Certificate or Matriculation	25	84·0
	Secondary or Grammar only	None	11	36·4
		School Certificate or Matriculation	24	66·7
	Other	None	10	40·0
		School Certificate or Matriculation	5	(60·0)
	All Schools	None	37	43·2
		School Certificate or Matriculation	54	74·1
18 and over	All Schools	None	16	37·5
		School Certificate or Matriculation and higher qualifications	23	65·2

(*ii*) students with previous hospital experience but no qualification;
(*iii*) students with nursing experience other than in hospital.

In 1946, 98 students who had previously obtained a nursing qualification proceeded to further training; of these 72 (73·5 per cent.) completed training, and, as would be expected, this proportion is significantly greater than the corresponding proportion (40·9 per cent.) for all students. There were 195 students in the second group, of whom 90 (46·1 per cent.) completed training. There were 105 students in the third group, of whom 54 (51·4 per cent.) completed training. The inclusion in the last group of an appreciable number of students who had previously served in the Royal Army Medical Corps is one reason for the relatively high success rate.

We had hoped to make a breakdown with regard to previous occupation of students without previous hospital nursing experience, but this information is not often recorded by hospitals. However, three broad headings (clerical, industrial, and domestic) account for about 60 per cent. of all those specified. Whereas a large proportion of students entering general training were recorded as having previously had a clerical occupation, most of those entering the mental training schools, whose previous occupations were known, had been employed in industry, domestic work, or H.M. Forces.

7. Degree of and Reasons for Wastage

Having reviewed certain aspects of the type of student nurse entering training schools in 1946, and having analysed separately the part that each plays in student wastage, we may here consider the overall wastage figures for the various types of training school. The reasons for wastage are classified under two headings:

(*i*) those relevant to students requested to leave,
(*ii*) those relevant to students who left of their own accord.

These reasons are shown in Table V with the proportion of successful students. The Table first shows that for training schools taken as a whole only 41 students out of every 100 complete training. This result agrees fairly closely with the findings of the Working Party set up in 1946 to examine the recruitment and training of nurses:

> out of every hundred student nurses that enter training not more than fifty remain at the end of the training period, and in many hospitals not more than thirty remain.

The wastage rates calculated by the Working Party for four types of training school are: General (37 per cent.), Mental (82 per cent.), Infectious Diseases (56 per cent.), Tuberculosis Sanatoria (65 per cent.). Except in the case of the general

TABLE V

DISPOSAL OF ALL STUDENTS

Percentage Distributions by Type of Training School

Disposal of Students	Type of Training School							Total
	General	Mental	Mental Deficiency	Fever	Tuber-culosis	Ortho-paedic	Ophthal-mic	
Failed to make educational grade in P.T.S.	4·6	—	1·5	3·8	7·1	—	—	3·6
Failed Preliminary State Exam. Part I	3·3	1·2	—	—	2·9	2·9	5·5	2·8
Failed Preliminary State Exam. Part II*	0·9	—	—	—	1·4	—	—	0·7
Asked to leave for reasons other than above	4·4	12·1	7·3	3·8	11·4	2·9	27·8	6·2
Total	13·2	13·3	8·8	7·6	22·8	5·8	33·3	13·3
Marriage	7·0	4·0	5·9	3·8	4·3	—	11·1	6·0
Sickness Self	6·0	4·6	1·5	—	5·7	11·4	—	5·6
Sickness Others	3·1	8·1	—	—	2·9	1·4	—	3·4
Transferred to other training	1·8	6·4	1·5	3·8	7·1	14·3	—	3·4
Unable to pass examinations	3·3	4·6	—	—	—	1·4	—	2·9
Financial reasons	0·9	9·8	29·4	3·8	1·4	—	—	3·6
Homesickness or domestic reasons	4·7	2·3	1·5	3·8	1·4	4·3	5·5	4·0
"Disliked nursing"	9·6	3·5	5·9	15·4	15·7	11·4	5·5	9·1
Left of own accord for reasons other than above	3·2	24·9	24·9	15·6	5·8	5·7	5·7	7·8
Total	39·6	68·2	70·6	46·2	44·3	49·9	27·8	45·8
Proportion of Successful Students to Total Intake	47·2	18·5	20·6	46·2	32·9	44·3	38·9	40·9
Grand Total	100·0 (866)	100·0 (173)	100·0 (68)	100·0 (26)	100·0 (70)	100·0 (70)	100·0 (18)	100·0 (1,291)

* This also includes failures where Parts I and II are taken together

training schools these results agree very closely with those given in Table V. Two reasons may account for the much higher figure (53 per cent.) for the General training schools in Table V:

(*a*) the different proportions of voluntary and municipal hospitals in the two studies (the Working Party found a difference in the wastage rates from 35 to 43 per cent);

(*b*) the wastage rates given by the Working Party related to an annual intake over the war years when there was less freedom of movement from one occupation to another.

Table V also shows that the proportion of students leaving of their own accord (46 per cent.) is much greater than the proportion requested to leave before completion of training (13 per cent.). This is true of each type of school, except the ophthalmic training schools, in which the numbers involved are too small to be meaningful. Failure in examinations is the principal reason for requesting students to leave, and 7 per cent. of all students entering the schools in 1946 left for this reason. A further 3 per cent. left after failing examinations, though not requested to do so. This brings the overall proportion to 10 per cent. Sickness, either of the student or of her relatives, accounts for a further 9 per cent. of the total who leave before completion of training, and a further 4 per cent. leave because of homesickness or for domestic reasons other than illness. The 6 per cent. wastage due to marriage (all types of training) includes only students leaving to get married *before* completion of training.

In addition 6 per cent. of successful students (Table VI) leave to get married after completion of training, and hence the total marriage wastage figure (*i.e.* of qualified and unqualified nurses) is about 9 per cent.

On the other hand, 3·4 per cent. of all entrants transfer to other training and are not necessarily lost to the hospital service; the proportion of such students in the case of orthopaedic training schools is as high as 14 per cent. Although slightly less than 4 per cent. of all entrants leave for financial reasons, the proportions for mental and mental deficiency training schools are as high as 10 per cent. and 29 per cent. respectively. These schools admit greater numbers of male students than the others, and it is male students in the age group 20–29 who are most likely to leave for more remunerative employment. Unfortunately, the specification of one major reason for student wastage is very vague; students leaving because they "do not like nursing" and, indeed, for no stated reason merit closer study.

Table VI gives the results of an analysis of the subsequent disposal of students who successfully completed training. It shows that 72 per cent. of such students were retained in the hospital service, and those who leave to get married or for other reasons are not necessarily lost to the service. About three-quarters of those qualifying for the mental and mental deficiency registers remain in the hospital at which they received their training, whereas about one-quarter of those qualifying at the General training schools proceed to midwifery training.

8. Length of Training

In relation to causes of student wastage, an issue of considerable importance is the length of training received by students who did not complete training (Table VII, overleaf).

The percentage distributions differ by type of training school, but the numbers involved at training schools other than general and mental are too small to justify definite conclusions. Of students leaving before completion of training at *General Training Schools*, 48·2 per cent. left during the first 6 months and a further 19·5 per cent. during the second 6 months. Corresponding figures for *Mental Training Schools* show that 39 per cent. left during the first

TABLE VI

DISPOSAL OF SUCCESSFUL STUDENTS

Percentage Distributions by Type of Training School

Disposal of Students	Type of Training School							Total
	General	Mental	Mental Deficiency	Fever	Tuber-culosis	Ortho-paedic	Ophthal-mic	
Retained in hospital	46·3	75·0	78·7	8·3	—	3·2	57·1	43·7
Took up appointment as Staff Nurse in another hospital	7·1	9·4	7·1	8·3	—	—	—	6·4
Joined H.M. Forces	0·2	—	—	—	—	—	—	0·2
Post-registration training excluding midwifery	2·2	6·25	7·1	41·7	—	—	—	3·2
Midwifery	24·2	—	—	—	—	—	—	18·7
Marriage	7·3	3·1	—	—	—	—	14·3	6·0
Other reasons	6·6	6·25	7·1	16·7	100·0	93·6	28·6	16·3
Not specified	6·1	—	—	25·0	—	3·2	—	5·5
Totals	100·0 (410)	100·0 (32)	100·0 (14)	100·0 (12)	100·0 (23)	100·0 (31)	100·0 (7)	100·0 (529)

TABLE VII

LENGTH OF TRAINING OF UNSUCCESSFUL STUDENTS

Percentage Distributions by Type of Training School

Length of Training	Type of Training School							Total
	General	Mental	Mental Deficiency	Fever	Tuberculosis	Orthopaedic	Ophthalmic	
Less than 3 mths	20·5	18·4	11·5	30·7	16·3	45·0	18·2	20·7
3–5 mths ..	27·7	20·6	5·8	23·1	34·9	10·0	9·1	24·0
6–8 „ ..	9·2	12·1	13·5	—	9·3	17·5	45·4	10·8
9–11 „ ..	10·3	14·2	21·1	23·1	11·6	—	9·1	11·5
12–14 „ ..	8·3	7·8	15·4	—	7·0	7·5	—	8·3
15–17 „ ..	3·3	4·3	7·7	—	7·0	—	—	3·7
18–20 „ ..	5·0	4·9	9·6	—	—	5·0	—	4·9
21–23 „ ..	5·0	2·8	—	7·7	—	2·5	—	3·8
2– yrs ..	6·6	7·8	5·8	15·4	9·3	7·5	18·2	7·3
3– „	3·5	4·3	1·9	—	4·6	5·0	—	3·6
4 yrs and over ..	0·6	2·8	7·7	—	—	—	—	1·4
Totals	100·0 (456)	100·0 (141)	100·0 (54)	100·0 (14)	100·0 (47)	100·0 (39)	100·0 (11)	100·0 (762)

6 months, and that 26·3 per cent. left during the second 6 months.

It will be noted that in the training schools as a whole 44·7 per cent. of students leaving before completion of training did so in the first 6 months and 22·3 per cent. in the second 6 months. A further 20·7 per cent left during the second year; the Table shows the proportions leaving in subsequent yearly periods.

It is apparent, therefore, that the majority of students (two out of every three on this evidence) who fail to complete their course leave during their first year, and that the majority of these do so in the first 6 months.

9. SUMMARY

The conclusions stated below are less comprehensive and more tentative than would have been those of an inquiry based on records pre-designed to explore all presumptively relevant types of information.

(1) Examination of the type of student entering a course of nurse training at hospitals of the Birmingham Region shows that before the minimum age of entry of 18 years was laid down, large proportions of students entering fever, orthopaedic, and ophthalmic training schools were under 18 years of age. Such students were more likely to leave than older entrants.

(2) Almost half the students entering the schools in 1946 were known to have received only the minimum of education, and the figures show a relatively high degree of wastage for this class of student.

(3) Success rates were far higher than average among students with previous nursing experience.

(4) Wastage levels in the various types of training school are given. The wastage rate of 82 per cent. for mental training was notable (the overall figure was 59 per cent.).

(5) Two out of every three students who failed to complete the course left during their first year, and of these the majority left in the first 6 months.

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PROVISION OF EMERGENCY BEDS IN HOSPITALS

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(1) Introduction

A number of beds are reserved each day in most hospitals to accommodate emergency cases arriving during the day. Since the number of emergency cases fluctuates considerably from day to day, it is not immediately obvious how many beds should be set aside for this purpose. If all the beds so reserved are filled during the day, any further emergency cases must either be accommodated in extra beds in the centre of a ward, or referred to another hospital. Neither of these expedients can be regarded as fully satisfactory. The former method involves extra duties for hospital staff, and the latter not only causes extra travelling for emergency cases, but also fails to guarantee a bed. In London, for example, where the transfer of applications for beds is very efficiently organized by the King Edward's Hospital Fund Emergency Bed Service, beds are not immediately available for 10 to 15 per cent. of the cases referred to the Service (Daley, 1953).

On the other hand, if a large number of emergency beds is provided to satisfy peak demands, many of them will remain empty on days of low demand. As emergency beds can only be reserved at the expense of the beds available for patients on the waiting list, wastage of this kind should be kept as low as possible. The problem thus resolves itself into balancing two opposing factors:

(*i*) the ratio of the number of emergency beds occupied to the number demanded, which we call E, the efficiency factor,

(*ii*) the ratio of the number of emergency beds occupied to the number reserved for this purpose, called F, the occupation factor.

In Section 2, we set up a simple mathematical model of the demand pattern, and consider the relationship between E and F. In Section 3, these theoretical results are compared with the actual demand figures recorded at a hospital.

(2) Mathematical Model

It has been found that where a large number of persons are subject to a small but constant risk of accident, the number of accidents in successive time-intervals varies according to a Poisson distribution. It is to be expected that in any set of time intervals in which the (small) probability of a patient requiring an emergency bed is constant, the demand for beds will also follow a Poisson distribution. That is, the probability of a demand for r beds in a day is given by:

$$p_r = e^{-m}m^r/r!$$

where m is the average daily demand.

Suppose a beds are provided. Then, so long as $r \leqslant a$, a demand for r beds can be fully satisfied, and $(a - r)$ beds will not be used. If, however, $r > a$ then all a beds will be occupied, and $(r - a)$ patients must be accommodated elsewhere. Let the mean number of beds occupied be b.

$$\text{Then } b = \sum_{r=0}^{a} rp_r + \sum_{r=a+1}^{\infty} ap_r$$

$$= m\sum_{r=0}^{a-1}\frac{m^re^{-m}}{r!} + a\sum_{r=a+1}^{\infty}\frac{m^re^{-m}}{r!}$$

$$= m\left\{1 - \sum_{r=a}^{\infty}\frac{m^re^{-m}}{r!}\right\} + a\sum_{r=a+1}^{\infty}\frac{m^re^{-m}}{r!}$$

$$= m\{1 - P(a, m)\} + aP(a + 1, m)$$

$$\text{where } P(c, m) = \sum_{r=c}^{\infty}\frac{m^re^{-m}}{r!}$$

Hence the efficiency of the scheme with mean demand m, and a beds provided is:

$$\mathrm{E} = \frac{b}{m} = 1 - P(a, m) + \frac{a}{m}P(a + 1, m),$$

and the occupation factor is:

$$F = \frac{b}{a} = \frac{m}{a}\left\{1 - P(a, m)\right\} + P(a + 1, m).$$

$P(c, m)$ is tabulated as the accumulated terms of Poisson's Exponential Binomial Limit (Molina, 1945).

It is clear that $E = F\ (= 1 - m^m e^{-m}/m!)$ when $m = a$, *i.e.*, when the number of beds supplied is equal to the mean daily demand. This, however does not solve the problem, as a high efficiency should be regarded as the first desideratum, the occupation factor being somewhat less important.

Values of E and F can easily be computed from the Tables of $P(c, m)$. In Table I, they are shown for mean daily demands of 5, 10, 15, 20, 25, and 30, with various values of a (the number of beds provided).

Example.—For a hospital with a mean daily demand for ten beds, the provision of twelve beds each day would mean that in the long run, a bed would be immediately available for 94·7 per cent. of the patients, and each bed would be occupied on 78·9 per cent. of the days.

TABLE I
EFFICIENCIES AND OCCUPATION FACTORS: THEORETICAL

Mean Demand m	Daily Provision a	E (per cent.)	F (per cent.)
5	5	82·5	82·5
	7	94·9	67·8
	8	97·6	61·0
	9	98·9	55·0
	10	99·6	49·8
10	10	87·5	87·5
	12	94·7	78·9
	13	96·8	74·4
	14	98·1	70·1
	15	99·0	66·0
15	15	89·8	89·8
	17	94·9	83·6
	18	96·6	80·5
	19	97·8	77·2
	20	98·6	73·9
20	20	91·1	91·1
	22	95·1	86·5
	23	96·5	83·9
	24	97·6	81·3
	25	98·4	78·7
25	25	92·1	92·1
	27	95·3	88·3
	28	96·5	86·2
	29	97·5	84·0
	30	98·2	81·8
30	30	92·7	92·7
	32	95·5	89·5
	33	96·6	87·8
	34	97·4	85·9
	35	98·1	84·1

From this Table, the hospital administrator can determine how many beds should be provided to ensure an efficient service. If a standard of 95 per cent. efficiency is set (nineteen out of twenty emergency cases have a bed immediately available), the numbers a of beds required, for different mean demands m would be:

m	5	10	15	20	25	30
a	7	12	17	22	27	32
F (%)	67·8	78·9	83·6	86·5	88·3	89·5

If we set the standard of E = 97·5 per cent. (only one in forty patients having to be accommodated elsewhere), the corresponding figures are:

m	5	10	15	20	25	30
a	8	14	19	24	29	34
F	61·0	70·1	77·2	81·3	84·0	86·0

From these we deduce the simple result that whatever the mean demand between the limits 5 and 30, a 95 per cent. efficiency can be achieved by providing two more beds than the mean demand, and a 97·5 per cent. efficiency by providing four more beds than the mean demand.

The increase of F with m for fixed E shows that a hospital dealing with a large number of emergency cases has considerably less bed wastage than a number of smaller hospitals with the same efficiency. Thus 34 beds are needed to provide a 97·5 per cent. efficient service in one hospital with a mean daily demand for 30 beds, but 42 beds would be required to provide as efficient a service in each of three hospitals with mean demands of ten each.

(3) Hospital Data

Does the mathematical model fit the facts? Data of the demand for emergency beds each day were obtained from a hospital, and compared with the theory. The Royal Victoria Infirmary, Newcastle-upon-Tyne, is a teaching hospital with 720 beds in 1950, drawing its patients from a wide area of North-East England. It can make the proud claim "we never refuse an emergency patient", a result achieved by setting up "centre-beds" whenever necessary. From a statistical point of view, this is very satisfactory, as the figures are unencumbered by possibly incomplete records of refused applications. There may be included a few cases accepted by this hospital after rejection by others, but as is usual with hospital data, it is impossible clearly to define the population served, and we must accept these cases as being proper to the teaching hospital.

A first analysis of the figures for each of the three years, 1950, 1951, and 1952, showed considerable divergence from the model. This was taken to indicate a change in the average demand. A complete analysis of the first year's figures showed that there was no significant difference in demand from month

to month, but the demand on Sundays was significantly lower than that on weekdays. Accordingly, the Sunday figures were separated and found not to vary from year to year.

In Table II we show the distributions of demands for weekdays in each of the three years, and for Sundays in all three years together. The expected demands assuming the Poisson distribution are also shown. In none of the four distributions is there a significant divergence from the model, as indicated by the χ^2 test.

TABLE II

HOSPITAL DATA : DISTRIBUTION OF DAILY DEMANDS OBSERVED AND EXPECTED VALUES

Number of Beds Demanded	Frequency							
	Weekdays						Sundays 1950–2	
	1950		1951		1952			
	Obs. No.	Exp. %	Obs. No.	Exp. %	Obs. No.	Exp. %	Obs. No.	Exp. %
4	0		1		1		1	
5	0		0		0		1	5·0
6	0		0		2		4	
7	2	6·7	0	9·5	0	5·7	1	
8	1		4		1		6	5·0
9	3		2		2		8	7·7
10	2		2		3		10	10·7
11	2		7	7·7	7	5·1	17	13·5
12	11	5·5	24	11·5	8	8·1	15	15·7
13	9	8·5	15	15·9	12	11·9	16	16·8
14	11	12·1	18	20·5	18	16·1	25	16·6
15	21	16·1	17	24·6	15	20·4	9	15·4
16	19	20·1	23	27·7	27	24·3	12	13·4
17	23	23·7	32	29·3	24	27·1	10	10·9
18	25	26·3	34	29·3	25	28·6	7	8·5
19	26	27·7	26	27·8	24	28·6	3	6·2
20	20	27·7	19	25·0	29	27·2	1	
21	23	26·4	20	21·4	20	24·6	0	
22	27	24·0	18	17·5	20	21·2	1	
23	15	20·9	15	13·7	18	17·5	2	
24	15	17·4	11	10·3	15	13·9	3	
25	17	13·9	6	7·4	17	10·6	2	
26	14	10·7	4	5·1	5	7·7	0	
27	11	7·9	0		9	5·4	0	
28	5	5·7	6		3		0	
29	2		2		4		0	11·4
30	3		1		4		1	
31	2		1		0		1	
32	1		2	8·8	0	9·8	0	
33	1	10·7	2		0		0	
34	1		0		0		0	
37	0		1		0		0	
38	0		0		1		0	
39	0		0		0		1	
Daily Average	19·8 $\chi^2_{17} = 17$		18·1 $\chi^2_{16} = 24·9$		19·1 $\chi^2_{17} = 15$		13·9 $\chi^2_{13} = 11·1$	

We must now test whether the theoretical efficiencies and occupation factors for different numbers of beds provided would have been achieved.

On the 312 weekdays in 1950, 6,165 beds were demanded, giving an average demand of 19·8. If 22 beds had been provided each day, 6,864 would have been made available altogether, and beds would have been immediately available for 5,839 patients. (This last figure is the sum of the total number of patients when the demand was less than 22, plus 22 times the number of days with a demand of 22 or more).

Thus E = 5,839/6,165 = 94·7 per cent;
F = 5,839/6,864 = 85·1 per cent.

The corresponding theoretical figures for mean demand 20, with 22 beds provided are:

E = 95·1 per cent.;
F = 86·5 per cent.

In Table III, the observed E and F for two and four beds more than the mean daily demand are shown for each of the four distributions from the hospital data. Their theoretical equivalents are shown in brackets.

TABLE III

EFFICIENCY AND OCCUPATION FACTORS: HOSPITAL DATA

Series	Daily Provision	E (per cent.)	F (per cent.)
Weekdays, 1950 (Mean demand 19·8)	22	94·7 (95·1)	85·1 (86·5)
	24	97·3 (97·6)	80·2 (81·3)
Weekdays, 1951 (Mean demand 18·1)	20	93·8 (95·0)	85·0 (85·5)
	22	96·6 (97·6)	79·5 (79·9)
Weekdays, 1952 (Mean demand 19·1)	21	94·5 (95·1)	85·9 (86·0)
	23	97·0 (97·6)	80·5 (80·6)
Sundays, 1950–2 (Mean demand 13·9)	16	93·1 (94·8)	80·6 (83·0)
	18	95·5 (97·8)	73·5 (76·1)

It will be noticed that in each case the theoretical model slightly overestimates E and F for any of the practical situations considered. This is due to the very long "tails" of the distributions shown in Table II, which are not sufficient to reject the hypothesis of a Poisson distribution using the usual χ^2 criterion, but are definitely abnormal observations on this hypothesis. The discrepancy is most marked in the "Sundays 1950–2" distribution, where the demands of 30, 31, and 39 beds upset the model. Although it would be possible to take account of these using a different mathematical model, the simplicity of the results would be lost. It is considered preferable to use the Poisson model, and accept the limitation that the method will slightly overestimate E and F if such extreme demands occur.

DISCUSSION

(*a*) *The Lower Sunday Demand.*—This is only partly explained by the fact that in an industrial area, the accident rate is lower when the factories, mines, and shipyards are closed, despite an increase in domestic and street accidents. Nor can the lower Sunday demand for emergency beds other than for accident cases be due to patients' reluctance to call a doctor on Sunday, as this would appear as a higher demand on Mondays than on other weekdays.

The suggested reason is that while some emergency patients are in immediate need of a bed, there are others whose demand for an emergency bed can be deferred for a few days until the appropriate clinic is to be held.

(*b*) *Seasonal Variations.*—In hospitals where the population or the hazards fluctuate annually, it is reasonable to divide the year into seasons, and to base the provision of beds on the mean demand for the relevant season, as we have here separated the Sunday demand.

In the present investigation, there was no appreciable seasonal fluctuation in demand in 1950, but there was a significant increase in the last 4 months of 1951, and a decrease in the last 4 months of 1952. Many *post hoc* causes might be suggested for this, but at the time the trends were unexpected. For this reason, no account has been taken of these fluctuations in the calculations.

(*c*) *Practical Considerations.*—The average demand for a whole year cannot be known until the end of the year. A "moving average" of the previous 6 months gives an estimate of the mean demand for the coming month. For an area where there is a large seasonal fluctuation, the average demand for the previous six months of the relevant season should be used. When seasonal and Sunday averages have been worked out, the results of Section 2 should be applied to each season separately.

(*d*) *Further Investigation.*—As has been pointed out recently (*Lancet*, 1953), an annual increase in the demand for emergency beds due to acute respiratory disease or heart-failure precipitated by bronchitis occurs at regional-board hospitals, but is hardly noticed at all at teaching centres.

The mathematical model and its consequences have so far been tested only against data from a teaching hospital. It is intended to continue this investigation by collecting data from other types of hospitals serving other areas.

It has been assumed in this paper that an emergency case can be assigned to any vacant emergency bed. Alternatives to this simplifying assumption also remain to be considered.

Summary

The problem of the number of hospital beds to be reserved for emergencies is considered.

A simple mathematical model of the demand pattern is suggested, and tested against hospital data.

It is found that any scheme for the provision of emergency beds should take into account constant seasonal differences, if any, including in particular any difference in the demand pattern on Sundays as compared with weekdays. When this is done, it is shown that for average daily demands of between 5 and 30 beds:

(*i*) Two more beds than the average daily demand should be provided to ensure a bed immediately available for 95 per cent. of emergency cases.

(*ii*) Four more beds than the average daily demand ensure a bed for 97·5 per cent. of cases.

The bed-occupation factors of these schemes are also studied.

I should like to thank Mr. N. T. J. Bailey for suggesting this problem, and the House Governor and Records Officer of the Royal Victoria Infirmary, Newcastle-upon-Tyne, for providing the data.

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